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OF THE

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VOLUME XIV.

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OF THE

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PROCEEDINGS

OF THE

Cambridge Philosophical Society.

A relation between the velocity and volume of organic ions in ueous solutions. By G. A. CARSE, Emmanuel College, and H. LABY, Emmanuel College, 1851 Exhibition Scholars. ommunicated by Professor Thomson, F.R.S.)

[*Read* 12 Nov. 1906.]

In a previous number of the Proceedings*, we have shown that eoretical and experimental considerations suggest that the tion of an ion in electrolytic conduction is analogous to the tion of a small body through a viscous medium. To test this w of the mechanism of electrolytic conduction, the linear nensions of a number of the ions of homologous organic acids l bases were calculated from molecular volumes and the atomic ume of hydrogen. It was found that the products, ionic volume inear dimension of the ion, were sensibly constant for the mbers of such homologous series.

This was shown to be in accordance with the hydrodynamical ation

$$va = \frac{F}{S\mu},$$

ere F is the driving force acting on the ion, v its velocity, a its ear dimension, S a constant depending on its shape, and μ the cosity of the electrolyte. In the case of a sphere moving ough a fluid with no slipping this equation is

$$va = \frac{F}{6\pi\mu}.$$

When very dilute aqueous solutions at a given temperature, ionic velocities under a field of one volt per cm. are con- ered, μ and F are constant, and the value of va for a given ion als the product of a constant into an expression depending on shape of that ion. It would thus appear that the similarity shape of the ions of a homologous series would lead to the stancy of va for such a series. In the paper referred to va has n calculated for 7 fatty acids, 5 homologues of pyridine, 8 of ine, and 11 amines, the values given below being obtained:—

* *Camb. Phil. Soc.* Vol. XIII, pt v, p. 287 (1906).

Ion of	Va.	Ion of	Va.	Ion of	Va.
Formic acid...	17·9	Ethyl amine	21·3	Aniline	18·1
Acetic ,, ...	15·7	Allyl ,,	19·7	Methyl aniline	18·7
Propionic ,, ...	15·4	Propyl ,,	19·6	*o*-Toluidine	17·8
Butyric ,, ...	14·9	Isopropyl ,,	19·8	[*p*-Toluidine*...	17·3
Isobutyric acid	15·1	Diethyl ,,	19·0	*m*-Toluidine....	17·4
n-Valeric ,,	14·9	Isobutyl ,,	18·8	Benzylamine...	18·2
n-Caproic ,,	14·8	Isoamyl ,,	18·5	Ethylaniline...	17·1
		Dipropyl ,,	17·7	Diethylaniline..	17·3
Pyridine.....	21·4	Triethyl ,,	18·8		
α-Picoline	20·3	Benzyl ,,	18·2	* A solid.	
α–α′ Lutidine..	19·8	Diisobutyl ,,	16·7		
Ethyl pyridine	20·0	Tripropyl ,,	16·3		
α-Collidine	19·7				

Ionic Volumes and Velocities.

The velocities have been obtained from Bredig's memoir* a converted into centimetres per second per volt per centimetre multiplying his values by $1{\cdot}1 \times 10^{-5}$.

In finding the value of the cube root of the ionic volume a, t methods of the previous paper have been somewhat extend The calculation of the ionic volumes can be best explained means of the following examples:—

(1) Volume of the cation, trimethyl-α-naphthyl-ammonium,

$$C_6H_4 : \begin{matrix} C\dot{N}(CH_3)_3 : CH \\ CH \quad\quad : \dot{C}H \end{matrix} \text{ or } C_{13}H_{16}\dot{N}.$$

The molecular volume of 1-naphthylamine -5 : 6 : 7 : 8-tet hydride,

$$\begin{matrix} CH_2.CH_2.CH : CNH_2 : CH \\ \dot{C}H_2.CH_2.\dot{C}H.CH \quad : \dot{C}H \end{matrix}, \text{ at } 16°\text{C.} = \frac{147{\cdot}1}{1{\cdot}062} = 138{\cdot}6$$

$$+ (C_3H_7)_v = 13 \times 5{\cdot}3 \quad \ldots\ldots\ldots\ldots\ldots\ldots = 68{\cdot}9$$

$$207{\cdot}5$$

$$- \text{volume of 4 hydro H atoms} \ldots\ldots\ldots\ldots = 16{\cdot}0$$

$$\therefore (C_{13}H_{16}\dot{N})_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = 191{\cdot}5$$

$$\therefore \text{cube root of } (C_{13}H_{16}\dot{N})_v \ldots\ldots\ldots\ldots\ldots = 5{\cdot}76$$

which is a for this ion.

Note—

$$(C_6H_6)_v \text{ at } 0°\text{C.} = \frac{78}{{\cdot}900} = 86{\cdot}6$$

$$(C_6H_{12})_v \text{ at } 0°\text{C.} = \frac{84{\cdot}1}{{\cdot}760} = 110{\cdot}7$$

thus 6 hydro H atoms = 24·1.

* *Zeit. f. Phys. Chem.* XIII, p. 191 (1894).

(2) Volume of the cation, β-chlorethyl-trimethyl-ammonium, $CClH_2 . CH_2(CH_3)_3\dot{N}$, $= C_5H_{13}Cl\dot{N}$.

The molecular volume of triethylamine,

$C_6H_{15}N$, at 20°C.	$= 138{\cdot}9$
$+ Cl_v$	$= 21{\cdot}5$
	$160{\cdot}4$
$-(CH_2)_v$	$= 21{\cdot}2$
$\therefore (C_5H_{13}Cl\dot{N})_v$	$= 139{\cdot}2.$

Following H. Kopp $C_v = 2H_v$ has been used, and since $_v = 5{\cdot}3$ is used as previously, $C_v = 2H_v = 10{\cdot}6$. Using these lues and the molecular volumes of CH_3Cl, CH_2Cl_2, C_2H_5Cl, H_7Cl, $H_2CCl . ClCH_2$, $CH_3 . CHCl_2$, $CHCl_3$, CH_3CCl_3, CCl_4, e value 21·5 is obtained for the atomic volume of chlorine. her atomic volumes given in the table have been obtained in a nilar way.

That these methods of calculating ionic volumes, and so values a are satisfactory is shown by the agreement of the values of a tained in different ways for the same ion, e.g.,

Ion	Compound used for calculating ionic volume	a, cube root of ionic volume
Tetramethylammonium	$(C_2H_5)_2HN$.....	4·77
	n-$C_4H_7 . H_2N$	4·72
Trimethylphenylammonium	$C_6H_5H_2N$	5·43
	$C_6H_5CH_3HN$	5·40
	$C_6H_5(CH_3)_2N$.....	5·35

Other examples of this agreement will be found in the table.

Explanation of Table.

The table contains the ionic velocities and the data used for lucing the cube roots of the ionic volumes. The densities uld not all be obtained at the same temperature, but the mperatures selected were in as many cases as possible the same each series. In a number of cases it was possible to calculate coefficients of volume expansion with temperature, and thus to duce the densities at 25°C. These are indicated in the table by contraction 'cor.' after the temperature in the density column. shown in our last paper an error in a density affects the duct, va, in the last column of the table to about one third of extent that the same error in an ionic velocity does.

Ion	Ionic formula
Organic ammonium cations:	
Ethyl ammonium	$C_2H_5H_3N^{\cdot}$
Propyl „	$C_3H_7H_3N^{\cdot}$
Allyl „	$C_3H_5H_3N^{\cdot}$
Tertiary butyl ammonium	$(CH_3)_3CH_3N^{\cdot}$
Tetramethyl „	$(CH_3)_4\dot{N}$
Methyl diethyl „	$CH_3(C_2H_5)_2H\dot{N}$
Trimethylethyl „	$(CH_3)_3C_2H_5N^{\cdot}$
β Chlorethyltrimethyl ammonium	$CClH_2 . CH_2 . (CH_3)_3\dot{N}$
β Bromethyltrimethyl „	$CBrH_2 . CH_2(CH_3)_3\dot{N}$
Trimethylallyl ammonium	$(CH_3)_3C_3H_5N^{\cdot}$
Dimethyldiethyl „	$(CH_3)_2(C_2H_5)_2N^{\cdot}$
Trimethylpropyl „	$(CH_3)_3C_3H_7N^{\cdot}$
Triethyl ammonium	$(C_2H_5)_3HN^{\cdot}$
Trimethylisobutyl ammonium	$(CH_3)_3C_4H_9N^{\cdot}$
Methyltriethyl „	$CH_3(C_2H_5)_3N^{\cdot}$
Iodomethyl triethyl „	$CH_2I(C_2H_5)_3N^{\cdot}$
Tetraethyl ammonium	$(C_2H_5)_4N^{\cdot}$
Triethylallyl „	$(C_2H_5)_3C_3H_5N^{\cdot}$

d used for volume	Molecular weight of compound, M	Density, (gms. per c.c.) /temp. deg. C.	Molecular volume, M/ρ	Ionic volume	Cube root of ionic volume	Ionic velocity, cm./sec., per volt/cm. at 25° C. $\times 10^4$	Ionic velocity × cube root of ionic volume $\times 10^4$
ne.....	45·1	·689/15	65·5	70·8	4·14	5·15	21·3
ine.....	59·1	·714/25	82·8	88·1	4·45	4·41	19·6
ie	57·1	·768/19	74·3	79·6	4·30	4·57	19·7
butylamine .	73·1	·690/25	105·9	111·2	4·81	4·03	19·3
nine.....	73·1	·706/20	103·5	108·8	4·77	4·80	22·9
nine	73·1	·733/26	99·7	105·0	4·72	4·80	22·6
mine.....	101·1	·728/20	138·9	123·0	4·97	3·94	19·6
nine.....	73·1	·706/20	103·5	130·0	5·07	3·94	20·0
mine.....	101·1	·728/20	138·9	123·0	4·97	4·44	22·1
mine..... of Cl = 21·5	101·1	·728/20	138·9	139·2	5·18	4·10	21·2
mine..... of Br = 25	101·1	·728/20	138·9	142·7	5·23	3·98	20·8
ie.....	57·1	·768/19	74·3	143·2	5·23	4·19	21·9
mine.....	101·1	·728/20	138·9	144·2	5·24	4·20	22·0
mine	59·1	·714/25	82·8	151·7	5·33	3·98	21·2
mine.....	101·1	·728/20	138·9	144·2	5·24	3·59	18·8
mine.....	73·1	·735/15	99·5	168·4	5·52	3·73	20·6
mine.....	101·1	·728/20	138·9	165·4	5·49	3·78	20·8
nine..... of I = 28·9	101·1	·728/20	138·9	189·0	5·74	3·39	19·5
mine.....	101·1	·728/20	138·9	186·6	5·71	3·54	20·2
e.....	57·1	·768/19	74·3	206·8	5·91	3·46	20·5
lamine.....	99·1	·771/18	128·5	197·4	5·82	3·46	20·2

Ion	Ionic formula
Triethylpropyl ammonium.....	$(C_2H_5)_3C_3H_7\dot{N}$ .....
Triethylisobutyl ,, ...	$(C_2H_5)_3C_4H_9\dot{N}$ .....
Triethylisoamyl ,, ...	$(C_2H_5)_3C_5H_{11}\dot{N}$ .....
Diisoamyl ammonium.....	$(C_5H_{11})_2H_2\dot{N}$ .....
Organic ammonium cations of the homologues of aniline:	
asy. *m*-Xylidine	$C_6H_3(CH_3)_2H_3\dot{N}$ .....
Dimethylaniline	$C_6H_5(CH_3)_2H\dot{N}$ .....
ψ Cumidine.....	$1:3:5:6\ C_6H_2(CH_3)_3\dot{N}H_3$ ....
Trimethylphenyl ammonium.....	$(CH_3)_3C_6H_5\dot{N}$ .....
Dimethylethylphenyl ammonium	$(CH_3)_2C_2H_5C_6H_5\dot{N}$ .....
Trimethyl α naphthyl ,,	$C_6H_4\begin{cases}\dot{C}\dot{N}(CH_3)_3:CH\\ CH:\dot{C}H\end{cases}$ .....
Trimethyl β naphthyl ,,	$C_6H_4\begin{cases}CH:\dot{C}\dot{N}(CH_3)_3\\ CH:\dot{C}H\end{cases}$ .....
Organic ammonium cations of the homologues of pyridine and quino	
Piperidine	$C_5H_{11}H\dot{N}$ .....
Pyridine methylium	$CH_3.\dot{N}:CH.CH$ $\dot{C}H:CH.\ddot{C}H$ .....

nd used for volume	Molecular weight of compound, M	Density, (gms. per c.c.) /temp. deg. C.	Molecular volume, M/ρ	Ionic volume	Cube root of ionic volume	Ionic velocity, cm./sec., per volt/cm. at 25° C. $\times 10^4$	Ionic velocity × cube root of ionic volume $\times 10^4$
amine.....	101·1	·728/20	138·9				
nine	59·1	·714/25	82·8	208·8	5·93	3·24	19·2
of N = 2·3							
amine.....	73·1	·735/15	99·5				
umine.....	101·1	·728/20	138·9	225·5	6·09	3·20	19·5
of N = 2·3							
mine	87·1	·749/18	116·2	248·7	6·29	2·89	18·2
lamine.....	157·2	·770/25 cor.	204·2	209·5	5·94	2·66	15·8
line	121·1	·918/25	131·8	137·1	5·16	(3·30)	(17·0)
laniline	121·1	·957/20	126·5	131·8	5·09	(3·72)	(18·9)
ine.....	135·1	·963/	140·3	145·6	5·26	(3·21)	(16·9)
.....	93·1	1·018/25	91·5	160·4	5·43	3·77	20·5
niline	107·1	·976/15	109·7	157·4	5·40	3·77	20·4
laniline	121·1	·957/20	126·6	153·1	5·35	3·77	20·2
niline.....	149·1	·936/18	159·3	164·6	5·48	3·62	19·8
iline	135·1	·949/18	142·3	168·8	5·53	3·62	20·0
hylamine — tetrahydride	147·1	1·062/16	138·6				
robenzene...	84·1	·76/0	110·7	191·5	5·76	3·37	19·4
.....	78·0	·900/0	86·6				
ro H = 4							
hylamine — tetrahydride o H = 4	147·1	1·031/16	142·7	195·6	5·81	3·34	19·4
e	85·1	·859/25	99·0	104·4	4·71	3·94	18·6
... .	79·0	·985/15	80·2	106·7	4·74	4·87	23·1

Ion	Ionic formula
Dimethylpyridinium	$H\dot{N}:C.CH_3.CH$
	$\dot{C}H:CH.\ddot{C}.CH_3$
	$C_7H_{10}N^{\cdot}$
	$C_7H_{10}N^{\cdot}$
Pyridine ethylium	$C_2H_5.\dot{N}:CH.CH$
	$\dot{C}H:CH.\ddot{C}H$
α Picoline methylium	$CH_3.\dot{N}:CCH_3.CH$
	$\dot{C}H:CH.\ddot{C}H$
α Picoline ethylium	$C_2H_5.\dot{N}:CCH_3.CH$
	$\dot{C}H:CH.\ddot{C}H$
α Lutidinemethylium	$CH_3.\dot{N}:CCH_3.CH$
	$\dot{C}.CH_3.CH.\ddot{C}H$
Collidine	$H\dot{N}:CH.CH$
	$\dot{C}CH_3:CH.\dot{C}C_2H_5$
Isoquinoline	$C_9H_7H\dot{N}$
Quinoline	$C_6H_4\begin{matrix}{}^{\cdot}CH:CH\\ {}^{\cdot}\dot{N}H:\dot{C}H\end{matrix}$
4-Methyl quinoline	$C_6H_4\begin{matrix}{}^{\cdot}CCH_3:CH\\ {}^{\cdot}\dot{N}H:\dot{C}H\end{matrix}$
Quinoline methylium	$CH_3\dot{N}C_9H_7$
Isoquinoline methylium	$C_9H_7\dot{N}CH_3$

d used for volume	Molecular weight of compound, M	Density, (gms. per c.c.) /temp. deg. C.	Molecular volume, M/ρ	Ionic volume	Cube root of ionic volume	Ionic velocity, cm./sec., per volt/cm. at 25° C. $\times 10^4$	Ionic velocity × cube root of ionic volume $\times 10^4$
thylpyridine	107·1	·930/25 cor.	115·2	120·5	4·94	(4·03)	(19·9)
thylpyridine	107·1	·922/25 cor.	116·1	121·4	4·95	(4·03)	(19·9)
line thylpyridine	107·1	·941/25 cor.	113·9	119·2	4·92	(4·03)	(19·8)
.....	79·0	·985/15	80·2	127·9	5·03	4·26	21·5
.....	93·1	·933/22	99·8	126·3	5·02	4·28	21·5
.....	93·1	·933/22	99·8	147·5	5·28	3·86	20·4
thylpyridine	107·1	·922/25 cor.	116·1	142·6	5·22	3·87	20·2
e.....	121·1	·922/15	131·3	136·6	5·15	(3·83)	(19·7)
.....	129·1	1·091/25 cr.	118·3	123·6	4·98	(3·87)	(19·3)
....	129·1	1·091/25 cr.	118·3	123·6	4·98	(3·86)	(19·2)
.....	143·1	1·083/25 cr.	132·1	137·4	5·16	(3·48)	(18·0)
.....	129·1	1·091/25 cr.	118·3	144·8	5·25	4·02	21·1
.....	129·1	1·091/25 cr.	118·3	144·8	5·25	4·03	21·1

Ion	Ionic formula
Coniine	$C_3H_7 . HC \begin{matrix} .H_2\dot{N} . CH_2 . \\ \cdot CH_2 . CH_2 . \end{matrix} CH_2$
Menthyl ammonium	$C_3H_7 . CH \begin{matrix} .CH_2 . CH_2 . \\ .CHNH_3 . CH_2 . \end{matrix} CH$
Organic phosphonium cations:	
Tetraethyl phosphonium	$(C_2H_5)_4P^{\cdot}$ .....
Methyltriphenyl phosphonium ...	$CH_3(C_6H_5)_3P^{\cdot}$ .....
Ethyltriphenyl „ ...	$C_2H_5(C_6H_5)_3P^{\cdot}$ ....
Propyltriphenyl „ ...	$C_3H_7(C_6H_5)_3P^{\cdot}$ .....
Triphenylbenzyl „ ...	$(C_6H_5)_3C_7H_7P^{\cdot}$ .....
Organic arsonium cations:	
Tetramethyl arsonium	$(CH_3)_4As^{\cdot}$ .....
Tetraethyl „	$(C_2H_5)_4As$ .....
Organic stibonium cations:	
Tetramethyl stibonium	$(CH_3)_4Sb^{\cdot}$ .....
Tetraethyl „	$(C_2H_5)_4Sb^{\cdot}$ .....

l used for olume	Molecular weight of compound, M	Density, (gms. per c.c.) /temp. deg. C.	Molecular volume, M/ρ	Ionic volume	Cube root of ionic volume	Ionic velocity, cm./sec., per volt/cm. at 25° C. $\times 10^4$	Ionic velocity × cube root of ionic volume $\times 10^4$
.....	127·1	·849/25	149·7	155·0	5·37	3·08	16·6
mine	155·2	·862/20	180·1	185·4	5·70	2·86	16·3
phosphine	118·1	·812/15·5	145·4	193·1	5·78	3·37	19·5
nethyl ,, ... $_6H_5 = 80·8$.	200·1	1·078/15	185·6	266·4	6·43	2·65	17·1
nethyl ,, ...	200·1	1·078/15	185·6	287·6	6·60	2·57	17·0
nethyl ,, ...	200·1	1·078/15	185·6	308·8	6·76	2·51	17·0
phosphine . $_5H_5 = 80·8$, $_7H_7 = 96·0$.	186·1	1·07/16	173·9	345·4	7·02	2·46	17·3
rsine	162·1	1·151/16·7	140·8	103·7	4·70	4·18	19·6
rsine	162·1	1·151/16·7	140·8	188·5	5·73	3·29	18·9
stibine ...	165·3	1·523/15	108·6	135·1	5·13	3·52	18·1
tibine	207·3	1·324/16	156·6	204·3	5·89	3·02	17·8

Discussion of Table.

The last three columns of the table show that the velocity o the ion of a member of a homologous series of the organic base examined varies inversely as the cube root of its ionic volume, fo the product of these is sensibly constant. The mean value of th product *va* for the 22 ammonium ions is 20·2, for the 7 homologue of aniline 18·8, for the 13 homologues of pyridine and quinolin 20·3, for the 5 phosphonium ions 17·6, for the 2 arsonium ions 19·3 for the 2 stibonium ions 18·0, and for coniine and menthylamin 16·5.

Including this paper and the last paper we have calculated th value of the product *va* for some 80 substances.

Conclusions.

1. The value of the product ionic velocity into the ion linear dimension, or *va*, has been calculated for the cations of organic bases in aqueous solution. The ionic volumes, of whi the ionic linear dimension is the cube root, have been found fr molecular and atomic volumes. It is found that for the ions o given series of the organic bases investigated, amines, homologu of aniline, homologues of pyridine and quinoline, phosphin arsines, and stibines, this product *va* is constant.

2. It has been shown that these results may be accounted by considering the motion of an ion through an electrolyte similar to that of a small body through a viscous medium, under these conditions the ionic velocity, for ions of a given sh would be inversely proportional to the ionic linear dimension.

Note on a Collection of Oribatidae from British Guiana.

C. Warburton, M.A., Christ's College, and N. D. F. Pearce, A., Trinity College.

[*Read* 29 October, 1906.]

The Oribatid mites are minute creatures, seldom exceeding mm. in length, and often barely visible to the naked eye. is only natural, therefore, that all except the very largest ms should escape the notice of the naturalists upon scientific peditions, and of those who, dwelling in out of the way parts the world, are good enough to collect and send home the re obvious specimens of insects and arachnids of their locality. e consequence is that our knowledge of the Oribatidae depends ost exclusively on species found in Europe and the United tes—found, in fact, where naturalists who have studied this up can examine them on the spot. Nor did there appear any lihood of our acquaintance with exotic Oribatidae being atly extended, for even if an expert in Arachnology were sent on a scientific expedition he would lack the time and apparatus necessary for the collection and preparation of such all objects.

There is no need to insist on the unsatisfactory nature of lassification based upon a very limited fauna in any group of mals. The Araneae furnish a striking example, as those mals were a few years ago precisely in the position now upied by the Oribatidae. A more complete study of exotic lers has completely revolutionised the classification of the up which had hitherto been based upon a very restricted na.

We think it important to call attention to the fact that the all size of the Oribatidae need be no bar to a very thorough uaintance with the group, for we find that consignments of ss or other matter in which they live sent from the most ote localities reach England in such a condition that the es can be captured and examined alive. The very minimum rouble is entailed on the collector, who has only to see that moss is in good condition and not too dry, and to pack it tins which may be hermetically sealed without detriment to living contents.

The fact is well illustrated in the case of some tins of moss ch we received in July last from British Guiana. The moss

was tightly packed and the tins soldered up. On arrival, th moss was found to be teeming with life, and no fewer than fort species of Oribatidae new to science were collected from i This is the more striking inasmuch as the well-established specie already recognised do not number more than two hundred an fifty. We are not at present ready with a detailed report o these new forms, some of which are of extreme interest and wi necessitate the suppression of one accepted genus—*Phthiracar* —and the establishment of more than one new genus.

The importance of receiving the mites in a living conditio is not only due to the better preservation of the specime obtained, but also to the fact that it renders possible the u of Berlese's apparatus for the collection of minute insects a arachnids from the material in which they live. In this ingenio contrivance the creatures are induced, by the application of he to desert the moss or other material and to fall into a ves prepared for their reception, with the result that a very lar proportion of the creatures present are captured with an imme saving of labour.

The Radioactivity of the Alkali Metals. By NORMAN R. MPBELL, M.A., Trinity College, and ALEXANDER WOOD, B.A., manuel College.

[*Read* 12 November, 1906.]

§ 1. It has been shown in a recent paper* that the natural ioactivity of the elements is an atomic property, and that radioactivity of a compound can be calculated when that of constituent elements is known. This discovery makes it sible to investigate the activity of elements which could not examined previously with any convenience.

It seemed of especial interest to examine the alkali metals: ordingly experiments were made on potassium sulphate. The paratus and methods used were those described in the paper mentioned. It was found that this salt was much more ve than any substance previously tried which did not contain of the 'radioactive elements.' Thus the activity of lead as asured by the method adopted is 9·3 arbitrary units: that of assium sulphate is 70. But it soon became apparent that numbers for lead and for the potassium salt were not strictly nparable: for the rays from the potassium salt were far more etrating than those from the lead and were not all absorbed the air in the testing vessel. When a sheet of paper of a face density equal to that of a layer of air 3·5 centimetres k was placed over the potassium salt, so as to absorb the s coming from it, no appreciable difference in the ionisation observed. The same sheet of paper would cut out more n half of the ionisation due to the rays from lead or from any wn radioactive element.

§ 2. It seemed likely at first sight that the remarkable vity of the potassium salt was due to some radioactive urity contained in it. But on consideration it appears that impurity consisting of any of the known radioactive elements ld not account for the phenomena. By far the larger part he ionisation caused by such elements is due to the α rays tted by them: but the most penetrating α rays known would more than half absorbed by the sheet of paper which had effect on the ionisation due to the potassium. However a ematic search for an impurity was undertaken.

§ 3. (1) The sample of potassium sulphate used was tested an emanation. A saturated solution of the salt in water was ed in a closed vessel for four weeks. At the end of that

* *Proc. Camb. Phil. Soc.* XIII, p. 282.

period the air above the solution was drawn into a testing ves
No increase in the ionisation was observed. To indicate
sensitiveness of the test, it may be remarked that one-thirti
part of the radium emanation in a volume of Cambridge wa
equal to that of the solution would have been detected w
certainty. The presence of radium, thorium or actinium
negatived decisively by this test.

(2) Another sample of potassium sulphate was tried. T
first sample came through a local dealer from Messrs Harringt
the second was the purest sample which Dr. Kahlbaum co
supply. No difference in the activity of the two samples amou
ing to 5 % of the whole could be detected.

(3) Other salts of potassium were tried. The follow
table shows the results obtained and the values of the activ
of potassium calculated on the assumption that the activity
an atomic property and that none of the other elements contai
in the salts have an appreciable activity.

TABLE 1.

Salt	% of K in salt	Activity of salt	Activity of K	Weight of salt
K_2SO_4—Sample 1	44·7	489	1090	220
K_2SO_4—Sample 2	44·7	471	1050	215
KCl—Sample 1	52·1	495	951	135
KCl—Sample 2	52·1	495	951	139
KI	23·5	276	1180	232
KNO_3	38·6	388	1005	199
			Mean 1038	

The discrepancy of the values for potassium given in colun
are not greater than might be expected. The layers of the s
used were only ·15 cm. thick. This thickness may not be suffic
to absorb all the rays from the lowest stratum and hence
activity of the layer may depend somewhat on the density of
salt used. In the 5th column are given the weights of the la
of the respective salts: it will be seen that the smallest va
of the activity of potassium correspond to the least dense la

(4) All the potassium salts used in commerce are prep
from the same deposits of sylvine and kainite at Stassfurt.
is not impossible, therefore, that all potassium salts from
dealers should contain a common impurity. Accordingly s
were taken to procure potassium salts which were known t
derived from some other source. A considerable quantit

es from wood which had grown on the Sussex Weald was ained. These wood ashes were mixed with water and the ulting solution evaporated to dryness with sulphuric acid: e remaining solid consisted almost entirely of potassium sulphate xed with sufficient organic matter to turn it a light grey. The ivity was found to be 474 on the same scale as that of Table 1. e penetration of the rays was also tested by the method de- ibed in § 4 below. It was found that the decrease of ionisation sed by two layers of tin foil was 36 °/₀ in the case of the nmercial salts and 38·5 °/₀ in the case of the salt from the od ashes. It may be concluded that the activity of the potas- m does not depend on its place of origin.

A still more convincing experiment of the same nature was d. A specimen of orthoclase said to contain about 16·5 °/₀ potassium was procured. The operation of extracting the assium from the mineral was judged to be too tedious: the ivity of the mineral itself was tested, and found to be 201. all the activity had been due to the potassium it should e been 171, a value somewhat smaller. The difference may accounted for by the presence of a small quantity of radium he felspar, the presence of which was shown readily by testing the emanation. The decrease in the activity of the mineral en it was covered by one layer of tin foil was 40 °/₀: since tin foil was sufficient to cut out all the α rays of radium it to be expected that the decrease would be larger than when ire potassium salt was used. This expectation was confirmed: the tin foil cuts down the ionisation due to the potassium by 26·6 °/₀. However the decrease caused by a second layer in foil was 16 °/₀, and agrees well with the decrease found in same conditions for pure potassium salts, 17·2 °/₀.

These observations afford conclusive evidence that the active nt is either potassium itself or some element associated with niversally.

(5) An attempt was made to decide between these rnatives by subjecting a potassium salt to fractional crystal- tion. The first experiments were made upon potassium hate. 600 grammes of the salt were taken and divided into equal portions by crystallisation from a solution saturated 00° C. A difference in activity of 2 °/₀ was found, the crystals g slightly more active than the mother liquor. But when of the portions was recrystallised once more by the same nod, there was only a difference of 1 °/₀ (barely detectable) ween the extreme portions.

Similar experiments were tried with potassium nitrate. kilogram of the salt was recrystallised 18 times, the crystals g each time separated from the mother liquor, redissolved

and reprecipitated. The mother liquor of the first crystallisatio was compared with the crystals of the last, but no differenc in the activity could be detected. (It is important in makin these experiments that the specimens of the salt to be compare should be brought to precisely the same physical condition: f small differences in the density may make a difference in th quantity of the rays which escape unabsorbed from a com paratively thin layer of the salt.)

It was also tried whether aluminium hydrate or bariu sulphate precipitated in the solution of a potassium salt woul possess any abnormal activity. No such effect could be observe in the most careful experiments.

It must be concluded, then, that the activity is a propert of potassium itself. But it is still possible that some disintegra tion product may be found, for in all the experiments ju described some hours or days elapsed between the preparatio of the samples and their examination. Further experiments w be devoted to this question.

§ 4. Measurements were made of the penetration of the ra from potassium sulphate. The layer of the salt was covered sheets of tin foil and the decrease of the ionisation caused the addition of each layer was noted. Allowance was made f the activity of the tin foil itself. The results of these experimen are given in Table 2. The first column gives the number sheets of foil, the second the ionisation observed (corrected), t fourth the value of $\frac{\lambda}{\rho}$, where λ is the absorption coefficient a

TABLE 2.

No. of sheets	Ionisation	Decrease	$\frac{\lambda}{\rho}$
0	467		
1	361	106	27·2
2	299	62	20·0
3	265	34	12·7
4	240	25	10·6

The surface density of the tin foil is ·00945 grm./cm.^{2}

ρ the density of the tin. The specimen of tin foil used is t employed by Crowther* in his researches on the β rays

* *Phil. Mag.* Oct. 1906.

ranium: for those rays he found that $\frac{\lambda}{\rho} = 9{\cdot}5$. The margin of
ror in the determination of $\frac{\lambda}{\rho}$ is about one unit.

It will be seen that the rays are very heterogeneous. They
em to vary in penetration from that of the very penetrating
rays of uranium downwards. But there is no sharp break
the curve representing the relation between the absorption
d the thickness of absorbing material such as is found in the
se of uranium and other elements which emit both α and
rays.

§ 5. The other alkali metals have been examined to ascertain
hether they show the same remarkable phenomena as potassium.
odium, lithium and ammonium salts showed no more activity
an the salts of the least active metals, such as zinc. Rubidium
um was tried and found to give effects of the same nature and
out the same amount as the potassium salts. The activity of
bidium alum on the scale adopted throughout this paper is
8: but rubidium alum contains almost exactly one-sixth of
weight of rubidium metal. Hence the activity of the metal
768.

The rays from rubidium were found to be much less pene-
ting than those from potassium. The absorption of the tin
l for the rays was so great that paper was used in place of
e tin foil. It had been found that $\frac{\lambda}{\rho}$ for the same paper and
e rays from potassium varied from 10·4 to 5·0. The value of
e same quantity for the rays from rubidium is about 160.
e smaller intensity of the rubidium rays and their greater
sorption makes the accurate measurement of λ impossible.
Caesium alum was examined but showed no activity that
ld be measured.

§ 6. The relation between the activity of potassium, rubidium
l caesium deserves consideration.

The penetration of the rays from potassium suggests that they
β rays: no measurements have yet been made to determine
sign of any charge that they may carry, but it seems probable
t they will be found to be negatively charged. Now it is well
own that the alkali metals give off copious streams of negative
ctricity under the action of light, and it has been shown by
f. Thomson* that rubidium and the alloy of sodium and
assium give off negative electricity even in the dark. It
ms very probable that the negatively charged rays which he
ected consist, at least in part, of the ionising rays which have

* J. J. Thomson, *Phil. Mag.* Nov. 1905.

been described in the foregoing paragraphs. But under the action of light, caesium is more active than rubidium and rubidium than potassium: whereas the intensity of the ionising rays emitted is greater in the case of potassium than in that of rubidium, and greater for the latter metal than for caesium. However I do not think it is necessary to conclude that there is no connection between the two effects. For the intensity of the rays emitted by a thick layer of any substance depends on the absorption of the substance for the rays that it admits. If I_0 is a constant measuring the true activity of the substance and λ is its coefficient of absorption for its own rays, the intensity of the rays emerging from a layer of infinite thickness is $\frac{I_0}{\lambda}$. Now the penetration of the rays from rubidium is only $\frac{1}{10}$ of that of the rays from potassium. Hence if allowance is made for the difference of penetration it would appear that the ratio of the activity of rubidium to that of potassium is about 12.

The well-known relations between the properties of potassium, rubidium and caesium would lead us to expect that the difference between the rays from caesium and the rays from rubidium is of the same kind as that between the rays from rubidium and those from potassium: it is to be expected that the rays from caesium would be even less penetrating than those from rubidium. Caesium may be pouring off negatively charged rays at a greater rate than rubidium, but they may possess so little energy that they are incapable of ionising a gas. Such rays might give a large photo-electric effect but they would give no ionising effect.

(It is worth mentioning that the experiments described above cannot have been influenced by the photo-electric effect. The vessel containing the potassium is almost perfectly light-tight and no difference in the effect was observed whether the laboratory was filled with bright sunlight or dimly lit by artificial light.)

§ 7. The intensity of the ionisation caused by the rays from potassium sulphate was compared roughly with that caused by the α rays from uranium: an accurate comparison is impossible without erecting new apparatus, for, since the penetration of the rays is different, the proportion absorbed in the air of the testing vessel will be different. It was found that an area of a layer of uranium oxide ·785 cm.^{2} in area gave ·795 times the ionisation caused by a layer of potassium sulphate of the same thickness with an area of ·961 cm.^{2} (The uranium was covered by a sheet of tin foil to cut off the α rays.) Hence the activity of uranium as measured by the β rays from a layer ·15 cm. thick is about 1000 times that of potassium.

§ 8. The ratio between the activities of the elements as measured in this way showed that it might not be impossible to obtain a photographic impression from the potassium rays. The experiment was tried. A sensitive (Cadett Spectrum) plate was enclosed in a light-tight paper envelope and placed immediately under a thick brass plate pierced with several holes: on the brass plate a packet of paper containing potassium sulphate was placed. An exposure of 28 days was given: on development the outline of the plate and of the holes in it could be distinctly traced. Several other plates were exposed at the same time in such a

ERRATA.

P. 20, line 9 from top *for* admits *read* emits.
,, § 7 line 3 *for* α *read* β.
,, line 4 from bottom *for* ·961 *read* 961.

activities of different salts of potassium shows that the activity is an atomic property.

4. The penetration of the rays from potassium salts has been measured. The rays are heterogeneous and vary in penetrating power from that of the β rays of uranium downwards.

5. The activity of rubidium salts is less than that of potassium salts, and that of caesium, sodium and lithium salts is too small to be measured. The penetration of the rubidium rays is much smaller than that of the potassium rays.

6. Considerations are urged tending to connect this activity with the photo-electric effect.

7. The activity of potassium as measured by its ionising power is one-thousandth of that of uranium as measured by the ionisation caused by the β rays from that substance.

8. An attempt, which appears to be successful, has been made to obtain a photographic effect from potassium rays.

On the Maturation of the Germ-Cells in the Sawfly, Nematus ribesii (Third Note*), by L. DONCASTER, M.A., King's College.

[*Received* 20 November, 1906.]

In two previous notes to the Cambridge Philosophical Society (*Proc.* Vol. XII. p. 474 and XIII. p. 103), and in a fuller paper (*Q. J. M. S.* Vol. XLIX. p. 561), I have described the maturation of the egg in *Nematus ribesii*. Since in all mitoses, whether of the polar divisions or in the developing egg, 8 chromosomes were found, it was concluded that no reduction took place, and that both the polar mitoses were equational. At the time those papers were written I had not completed the study of the fertilized egg, so that no suggestion could be offered to explain the difficulty of how normal fertilization could take place if there is no reduction of chromosomes. For many months I was quite unable to follow the entrance of the spermatozoon into the egg and its conversion into the male pronucleus, and I have still failed to find the earlier stages, but after cutting some hundreds of eggs laid by impregnated females I succeeded in observing the conjugation of male and female pronuclei. When it had been shown that true fertilization ("syngamy") does take place, it was necessary to re-examine the maturation divisions, in order to explain the discrepancy between the existence of conjugation of male and female pronuclei and the absence of reducing divisions in the maturation of the egg.

Since the technical difficulties in investigating the early stages of the egg are considerable, I determined to work first at the maturation of the spermatozoa. In the spermatogonia the nucleus is large with about 8 chromatin masses and usually one or more plasmosomes. In mitoses 8 chromosomes are visible. In the prophase of the first spermatocyte division there are sometimes 8 but more often 4 chromatin masses; in the latter case each is generally more or less distinctly double or quadruple, suggesting that the primary 8 chromosomes have paired to form 4 "gemini." In the equatorial plate of the first division there are 4 chromosomes packed close together, and they seem to divide in the heterotype manner sending 4 to each pole. In the second division there are again 4, which divide so that 4 go into each spermatid. It appears therefore that in the spermatogenesis normal reduction takes place, the somatic number 8 being reduced to 4.

* A full paper with figures is being published elsewhere.

In the oogonial divisions there are also 8, but in the nuclei of ne ovarian wall in most if not all cases the number is greater; it generally 16 but perhaps sometimes more. Either therefore nese cells must be regarded as abnormal, as has been suggested y Wilson for similar phenomena in Hemiptera, or the 8 chromo- omes of the germ-cells must be compound, as Petrunkewitsch as asserted in the case of the Bee. In the later pupal stages no ivisions take place in the oogonia, but they undergo prolonged rowth with deposition of yolk.

When true reduction had been found in the spermatogenesis became necessary to re-examine the polar mitoses to see hether it does not sometimes at least occur in the egg also. In me eggs 8 chromosomes were found in the second polar mitosis, nfirming the opinion previously expressed that two equation visions might occur. But in other eggs there are only 4 chromo- mes in the second maturation division, each of which is about vice as large as the single chromosomes of the eggs in which are present. The reducing type of division is found both in gs of virgin and of impregnated females, and is therefore not nditioned by fertilization, and in one egg at least only 4 were sible in the blastoderm mitoses.

It must therefore be concluded that in some eggs no reduction kes place, and that such eggs may develop parthenogenetically, elding males; in other eggs separation of complete chromosomes curs, so that the chromosome number is halved, and such eggs e capable of fertilization and probably yield females. When not rtilized they may develop at least as far as the blastoderm stage, t possibly the great mortality among eggs and larvae from rgin females is due to the dying off of those containing the duced number of chromosomes.

Probably in species which yield females from virgin eggs and e normally not fertilized, no reduction takes place.

A delicate reaction for Carbohydrates. By H. J. H. Fenton, Sc.D., F.R.S., Christ's College.

[*Read* 26 November, 1906.]

In previous communications [Fenton and Gostling, *Trans. Chem. Soc.*, 1898, 554, and 1901, 807] it has been shewn that by the action of dry hydrogen bromide on ketohexoses, such as lævulose, a product is obtained which crystallises in large colourless oblique prisms and gives an intense purple colour with strong acids. This product was found on investigation to be ω bromo-methylfurfural $CHO - C_4H_2O - CH_2Br$. The corresponding chloro-compound, or chloride, can be prepared in a similar way and a number of other derivatives, such as the acetate, benzoate, iodide and hydroxide, are readily obtained by double decomposition of the bromide or chloride with metallic salts. The halogen atom is, in fact, highly reactive and is quantitatively precipitated by action of silver nitrate in alcoholic solution.

Experiments are being continued in the direction of effecting various syntheses by the introduction of this methylfurfural residue, or radicle (for which no convenient name has yet been suggested) into typical carbon compounds. In the course of these investigations it has been observed that when the bromo- or chloro-compound is acted upon by sodio-malonic ester, in alcoholic solution, considerable heat is evolved and the mixture turns bright red. If now the product is poured into water it readily dissolves, giving a solution which exhibits an intense blue fluorescence. The nature of this product, which has not yet been isolated in a pure state, is now under investigation. The formation of the fluorescent product is extremely characteristic and may be employed as a most delicate test for the presence of these methylfurfural derivatives.

It was previously mentioned (*loc. cit.*, 1898, 554, and 1901, 36[illegible] that the formation of bromo-methylfurfural, by the action of hydrogen bromide, affords a characteristic test for ketohexoses or for compounds which are capable of yielding ketohexoses by hydrolysis. The substance to be examined is acted upon by hydrogen bromide dissolved in an appropriate solvent, such as ether, and the production of bromo-methylfurfural is indicated by the intense purple colour which appears after some minutes. A more certain method of procedure, however, consists in iso[illegible]

ng the crystals of bromo-methylfurfural and estimating their nount. In this way it was shewn that ketohexoses and cellulose eld about 20 or 30 per cent. of the crystalline bromo-compound, hereas the aldose sugars give only about 2 or 3 per cent. of a sidue which is uncrystallisable. It was previously stated [*Trans. hem. Soc.*, 1901, 363] that if any of the bromo-compound is rmed by aldoses, its quantity is too small to be detected. By ie method described in the present communication however, it an be shewn that bromo-methylfurfural is actually formed, though in small quantity, even in the case of aldose sugars. is not improbable that this small quantity results from a partial ansformation of aldose to ketose under the influence of the rong acid employed. [Compare Ost. *Zeit. angew. Chem.*, 1905 (18), 70.]

By taking advantage of the highly sensitive reaction with alonic ester, which was mentioned above, one may detect the erest trace of bromo-methylfurfural and this test may consequently serve for the identification of all hexoses, whether aldose ketose.

The mode of operating is as follows: A minute quantity of the lid substance to be examined is slightly moistened with water, ixed with a drop or two of phosphorus tribromide* gradually ated on a water-bath to 90—100°, and kept at this temperature ntil the mixture has turned dark coloured. It is then cooled, rred with a little alcohol and a few drops of malonic ester; coholic potash is then added until the solution is alkaline. On w diluting the resulting mixture with a large volume of water, alcohol, the fluorescence is at once apparent.

The reaction is strongly marked even with the aldoses, but is, might be expected, more intense with ketose sugars and th cellulose. In comparison with the other pure hexoses amined, galactose appears to give the weakest indications; is fact is perhaps connected with the peculiar configuration galactose. [Compare Morrell and Crofts, *Trans. Chem. Soc.*, 02, 667, and Fischer, *Ber.*, 1894, 2031.]

A saturated aqueous solution of hydrogen bromide may be ployed in this test instead of phosphorus tribromide; the ter is, however, preferable in the case of substances which e less readily attacked, such as cellulose. The chlorides of osphorus may also be used, but their action is perhaps less rtain.

Positive results were obtained with dextrose, lævulose, galtose, sorbose, cane sugar, maltose, lactose, raffinose, starches,

* It is best to dissolve the tribromide in some inert solvent of sufficiently high ing point, such as toluene.

dextrins, cellulose in different forms, salicin, amygdalin, and th mixture of sugars resulting from the condensation of glycolli aldehyde.

No indication was given by arabinose, xylose, glycollic alde hyde, mannitol, erythritol, glycerol, gluconic acid, mucic acid inosite.

It appears, therefore, that this test may be used for th identification of all hexoses or of other carbohydrates, glucoside &c. which yield hexoses on hydrolysis.

The test appears to possess some advantages over most the usual colour-reactions for carbohydrates in that the effect restricted to the hexose, or polyhexose, nucleus. The fluorescer character of the solution, moreover, is a property which is le liable to be mistaken than is the mere shade of colour upon whic many of the other tests depend.

It is possible that this reaction may be found serviceable demonstrating the existence of hexose residues in complex natur products, such as proteid substances.

Addendum, Jan. 8, 1907.

Later experiments have shewn that this test may even applied to the detection of sugars in dilute aqueous solution the following modification is adopted:—

About 2 or 3 c.c. of the solution is poured on to an excess solid calcium chloride, so as to make a semi-solid mass; abo 10 c.c. of toluene, containing two or three drops of phosphor tribromide, is then added and the mixture is heated to boilin for a few minutes. About 1 c.c. of malonic ester and a litt alcohol are then introduced and the mixture is made just alkali with alcoholic potash. At this point a characteristic pink colo is usually observed. Excess of alcohol and a few drops of wat are then added, when the blue fluorescence becomes apparen either immediately, or after standing for a minute or two.

The Solubility of Stereoisomerides in Optically Active Solvents.

H. O. Jones, M.A., Clare College.

[*Read* 26 November, 1906.]

Some text-books of Organic Chemistry make the statement 'the solubilities of two optical antimers *must be* different in optically active solvent'; this statement is not supported by experimental evidence.

If this statement were true crystallization of a $d+l$ mixture in an active solvent should be a simple and elegant method of separating such a mixture into its components. Further, it would have an interesting bearing on the theory of solutions since it is difficult to see how there could be a difference in the solubility of d and l compounds unless there was combination between solvent and solute.

The subject was, therefore, considered to be worth investigating experimentally.

The solubility of d and l camphor and of d and l camphoroximes in rectified turpentine (d pinene) and in pure l amyl bromide was therefore examined.

The following data show that the compounds used were pure:

Camphor	$[\alpha]_D$	in 8 per cent. solution	in	ethyl alcohol	at	18° C.	$+41{\cdot}9°$,
,,	$[\alpha]_D$	,,	,,	,,	,,	,,	$-41{\cdot}8°$,
Camphoroxime	$[\alpha]_D$	in 3 per cent.	,,	,,	,,	,,	$-40{\cdot}0°$,
,,	$[\alpha]_D$	,,	,,	,,	,,	,,	$+39{\cdot}9°$.

The l amyl bromide gave

$$\alpha_D = +4{\cdot}6°$$ in a 1 decimetre tube at 18° C.

The turpentine used gave

$$\alpha_D = 4{\cdot}38°$$ in a 1 decimetre tube at 18° C.

It was found that the camphorsulphonic acids were not sufficiently soluble to make determinations of solubility possible and that the two borneols could not be obtained pure enough for the purpose.

The solvent and solute were allowed to stand together and shaken from time to time at a constant temperature until the refractory power of the solution became constant. The specific rotatories of the solutions of the d and l compounds were then determined and, in the case of the camphoroximes in turpentine, the solubility was determined directly by evaporating a weighed

quantity of the solution and weighing the residue. (This is i possible in the case of camphor on account of its volatility.)

(1) *d* camphoroxime in turpentine at 18° C.
α_D in a 2 decimetre tube = 2·30°.
Specific gravity = ·8784.
Solubility 8·68 grams. in 100 grams. of solvent.

(2) *l* camphoroxime in turpentine at 18° C.
α_D in a 2 decimetre tube = 18·24°.
Specific gravity = ·8782.
Solubility ·8·69 grams. in 100 grams. of solvent.

(3) *d* camphoroxime in *l* amyl bromide at 15° C.
α_D in a 1 decimetre tube = − 3·55°.
Specific gravity = 1·199.

(4) *l* camphoroxime in *l* amyl bromide at 15° C.
α_D in a 1 decimetre tube = + 11·48°.
Specific gravity = 1·199.

(5) *d* camphor in turpentine at 15° C.
α_D in a 1 decimetre tube = 23·07°.
Specific gravity = ·9028.

(6) *l* camphor in turpentine at 15° C.
α_D in a 1 decimetre tube = 16·52°.
Specific gravity = ·9030.

It is evident from the above results that the solubilitie *d* and *l* camphoroximes and of *d* and *l* camphors in an optic active solvent are absolutely identical.

A further confirmation of the result was obtained by crystalli two inactive (*d* + *l*) mixtures from turpentine several times examining the optical activity of the crystals.

Mandelic acid and *i*-camphoroxime were found to be q inactive after recrystallizing several times, so that the mixt were not separated in this way.

It will be observed that if the value of α_D for the solven subtracted from that of the solutions of *d* and *l* compound the above cases the rotatory power found for the solute is equal in magnitude and opposite in sign.

Thus for example

(3) *d* camphoroxime − 3·55° − 4·6° = − 8·15°,
(4) *l* „ + 11·48° − 4·6° = + 6·88°,

and similar differences in the other cases. Since there is an e quantity of solute of equal and opposite rotatory power in case it is necessary to explain this anomaly.

Solutions of the *d* and *l* isomerides of equal strength were m in the above solvents and their rotatory powers examined.

Thus ·407 gram. of *d* camphoroxime in 7·5 c.c. of amyl bromide
α_D in a 1 decimetre tube $= +1{\cdot}58°$.
ubtracting 4·6° we get $-3{\cdot}02°$ as the rotatory power of the
e.

·07 gram. of *l* camphoroxime in 7·5 c.c. of amyl bromide gave
a 1 decimetre tube $= 7{\cdot}42°$.
ubtracting 4·6° we get $+2{\cdot}82°$ as the rotatory power of the
e.

hese differences are small, but well outside the limit of
rimental error. They were found to be due to the fact
4·6° is not the rotatory power of 1 decimetre of the solvent
ining a solute. α_D for a mixture of equal volumes of the
solutions above in a 1 decimetre tube was found to be

ubtracting this we get $-2{\cdot}91°$ and $+2{\cdot}93°$ for the rotatory
r of *d* and *l* camphoroxime respectively.
imilar experiments were made with the camphoroximes using
ntine as solvent and with the camphors using turpentine and
bromide as solvents and exactly similar results were ob-
d.
may therefore be concluded that the solubility and rotatory
rs of *d* and *l* isomerides are identical in an optically active
ll as in an inactive solvent.

The influence of spectral colours on the sporulation of Saccharomyces. By J. E. Purvis, M.A., St John's College, and G. R. Warwick, B.A., Pembroke College, Cambridge.

[*Read* 29 October, 1906.]

The classical researches of Hansen on the sporulation of various species of Saccharomyces were confined to the time limits at various temperatures, and so far as we know no researches have been published on the influence of the spectral colours upon the sporulation, although Marshall Ward has noted the destructive effect of light on the spores of *S. pyriformis*. The aim of this preliminary paper is to describe experiments we have conducted in the University Chemical Laboratory, showing that rays of light of varying degrees of refrangibility influence the appearance and production of spores in various species of Saccharomyces, and particularly as to the time when the appearance of the spores was first visible. The spectral colours were obtained by passing the light of a powerful oil lamp through various coloured screens, and the Saccharomyces were incubated at a temperature of 24—25°C. the temperature never varying more than half a degree. Pure cultures of various species of Saccharomyces were used, and in every experiment fresh healthy cultures were developed in sterilised wort before seeding them on moist gypsum blocks. Each growth was microscopically examined, and if the slightest indications of granulation were seen, fresh cultures were developed in wort until the cells were plump and filled with clear ungranulated protoplasm. They were then ready for seeding on the gypsum blocks and the plates were placed in position in boxes whose front windows carried coloured screens. The cultures were microscopically examined from time to time, and the dates, times and conditions of the cells are described in the following notes.

Description of the Apparatus.

The apparatus consisted of several japanned tin boxes one side of each being occupied by a coloured screen. Gypsum blocks were placed on the floors of the boxes and they were kept moist by a little water carried on the floors. The upper surface of each block was seeded with a very thin layer of the Saccharomyces. The boxes with their contents were placed in an incubator kept at a temperature of 24°—25°C., and an oil lamp was placed opposite the glass door of the incubator so that its light issued

through the glass door and the coloured screens and then played upon the surface of the cultures on the gypsum blocks.

The screens acting as front windows of the tinned boxes were glass cells filled with various coloured liquids. In the case of red light in the series of experiments Nos. 1 and 2, there was a screen of red glass which passed the red and yellow rays, and in the later experiments the screen was of the same red glass with a water cell in front like that containing the green and blue solutions. The solution forming the green screen was a mixture of aqueous solutions of the dye known as Double Green (S.F.) and Naphthol Green B [c]; and the solution forming the blue screen was an aqueous solution of ammoniacal copper sulphate and crystal violet which cuts off all rays except the blue and violet. These three screens were spectroscopically examined, and they respectively transmitted the red, green and blue rays, so that the overlapping of the three completely obliterated the passage of light. In addition to the coloured screens, experiments were also conducted at the same time with ordinary light and in the dark. In the case of the former the screen contained merely distilled water; and in the latter, the seeded gypsum blocks were enclosed in a closed wooden box and placed at the back of the incubator. The seeded gypsum blocks were then all placed in their respective positions in the different boxes, and they were allowed to incubate at 24—25°C. with the light of the lamp placed in front of the glass door of the incubator.

Experiments.

In the first series of experiments pure cultures of Hansen's *S. Cerevisiæ I.* and *S. Ellipsoideus I.* were seeded in very thin layers on the surfaces of the gypsum blocks, and they were examined from time to time. The following is a detailed account of the observations.

14 February.

4 p.m. The blocks were seeded and left to incubate.

15 February.

9.15 a.m. The cells were very granular in the two series but there was no appearance of spores.

4.30 p.m. *Red Light.* The granules of some of the cells began to form sporulation rings.

Green light. No attempt at sporulation.

Blue light. No attempt at sporulation.

White light. No attempt at sporulation.

8.30 p.m. *Red light.* In Cerevisiæ the spores were almost complete; in Ellipsoideus the granulations were forming rings.

Green light. Showed faint indications of sporulation in Ellipsoideus; and they appeared to be stronger in the Cerevisiæ.

Blue light. Faint indications of spores in Ellipsoideus and in Cerevisiæ.

White light. Same appearance as in the red light; except that the spores of Cerevisiæ were slightly less developed.

16 February.

9.45 a.m. *Red light.* In Cerevisiæ there was nearly complete sporulation in most of the cells; and in Ellipsoideus there were occasional cells with spores.

Green light. In Cerevisiæ a certain amount of sporulation, but not very strongly. In Ellipsoideus there were slight indications of spore formation.

Blue light. In Cerevisiæ there were very faint indications of sporulation; and in Ellipsoideus they were very like the appearance in the green light.

White light. In Ellipsoideus, they were the same as in the red light; and in the Cerevisiæ there were some perfect spores, though not so many as in the red.

5.30 p.m. *Red light.* In Cerevisiæ there was perfect sporulation; and in Ellipsoideus there were a few more spores than when examined at 9.45 a.m.

Green light. In Ellipsoideus there were better indications of spores than at 9.45 a.m.; the spores were more marked. In Cerevisiæ the rings were more marked than at 9.45 a.m.

Blue light. Ellipsoideus had hardly changed since morning; and Cerevisiæ shewed faint indications of spores but changed very little since morning.

White light. Ellipsoideus had hardly changed since 9.45 a.m.; the spore rings appeared to be better marked; and Cerevisiæ shewed more perfect spores.

10.45 p.m. *Red light.* Ellipsoideus had made some advance and more cells shewed perfect spores. In Cerevisiæ there were perfect spores in every cell.

Green light. The sporulation rings of Ellipsoideus were slightly better marked; but there were no perfect spores. The Cerevisiæ did not shew any apparent change.

Blue light. In both Ellipsoideus and Cerevisiæ the appearance was the same as at 5.30 p.m.; the indications of sporulation were exceedingly faint.

White light. In Ellipsoideus the sporulation appeared to be slightly more advanced, though not to the same extent as in the red; whilst in the Cerevisiæ about 40—50 % of the cells had formed perfect spores.

17 February.

9.45 a.m. *Red light.* Ellipsoideus shewed marked advance; a certain number shewed perfect spores. Cerevisiæ had perfect spores in every cell.

Green light. Ellipsoideus was very similar in appearance as when examined at 10.45 p.m. (16 February). In Cerevisiæ the indications were apparently disappearing; the cells appeared to be very thin and watery.

Blue light. Ellipsoideus was unchanged, and the cells of Cerevisiæ were faint, thin and watery; indications of sporulation were apparently disappearing.

White light. Ellipsoideus was apparently the same as at 10.45 p.m. (16 February); and in Cerevisiæ there were perfect spores in most cells.

In the second series of experiments the gypsum blocks were seeded with very thin layers of pure cultures of Hansen's *S. Cerevisiæ I.* and *S. Pastorianus II.*, and in addition to the red, green and blue screens, a series of observations were taken with white light and a series in a covered box so that no light could reach them.

18 February.

10.45 a.m. The blocks were seeded and left to incubate.

19 February.

9.30 a.m. *Red light.* Cerevisiæ shewed faint though certain indications of sporulation; and Pastorianus shewed very faintly.

Green light. Cerevisiæ shewed very faint indications but not so advanced as in the red; there were no indications in Pastorianus.

Blue light. No indications in either Cerevisiæ or Pastorianus; the cells were very granulated.

White light. In both Cerevisiæ and Pastorianus the appearance was exactly as in the red.

No light. In Cerevisiæ, the appearance was like that in the green. Pastorianus shewed no indications except in one or two cells.

2.15 p.m. *Red light.* Cerevisiæ shewed strong indications of sporulation; as also did Pastorianus though not so markedly.

Green light. Cerevisiæ shewed indications but not so strongly as in the red. Pastorianus shewed very faint indications.

Blue light. In Cerevisiæ there were no indications of spores; in Pastorianus only a few cells shewed indications.

White light. Cerevisiæ shewed indications though not so strongly as in the red; whilst Pastorianus shewed very much like those in the red.

No light. Cerevisiæ was similar to that in the white light; and Pastorianus as in white and red, although it was doubtful if there was much advance.

6 p.m. *Red light.* In Cerevisiæ some cells were approaching the completion of sporulation; Pastorianus shewed a very slight advance; the indications of spores were not very strong.

Green light. In Cerevisiæ there were fair indications; in Pastorianus less advanced than in red.

Blue light. Very weak indications in Cerevisiæ; whilst Pastorianus were unchanged.

White light. Very strong indications in Cerevisiæ, although not so advanced as in the red; in Pastorianus the appearance was like that in the red.

No light. In both Cerevisiæ and Pastorianus the indications were similar to those in the green.

11.45 p.m. *Red light.* In Cerevisiæ there was a marked advance on the last; also Pastorianus had advanced very slightly.

Green light. Cerevisiæ had slightly advanced, whilst Pastorianus had not changed apparently.

Blue light. Very faint indications in Cerevisiæ; but apparently no indications in Pastorianus, except one or two cells here and there.

White light. Cerevisiæ shewed marked advance in sporulation though not so much as in the red; Pastorianus remained unchanged.

No light. Cerevisiæ shewed marked advance, though not so well developed as in the white light, but much more than in the green. Pastorianus was very similar to that in the green and the white light.

It appeared as if the Pastorianus cells were not very healthy, and no further observations were made upon them in this series. The observations were confined to the Cerevisiæ cells during the rest of the experiment.

20 February.

10 a.m. *Red light.* Cerevisiæ cells had more perfect spores than when examined at 11.45 p.m. (19 February).

Green light. One or two cells of Cerevisiæ had sporulated as in red, white light and no light; but the majority had not advanced, and the cells were becoming empty and thin looking.

Blue light. The indications in Cerevisiæ appeared to be vanishing; the cells were very empty.

White light. Some spores perfect in Cerevisiæ.

No light. Cerevisiæ shewed marked advance; and the sporulation had now proceeded as far as in the white light.

4.30 p.m. *Red light.* Shewed about 50 % or more of the cells with perfect spores.

Green light. Most of the cells appeared to be becoming empty and no indications of sporulation in them; although a few of them shewed strong indications and here and there there were perfect spores.

Blue light. Most of the cells appeared very faint and empty looking; although a few cells preserved the original very faint indications.

White light. About 30—40 % of the cells had perfect spores.

No light. The spores were almost as well developed as in the red; and more developed than in the white light.

11 p.m. *Red light.* The great majority of the cells had developed spores.

Green light. Very like the appearance when examined at 4.30 p.m.; even the more perfect spores had a curious empty look.

Blue light. No indications of sporulation were seen.

White light. Hardly any change from and since 4.30 p.m.; about 30—40 % of the cells shewed perfect spores.

No light. Strong sporulation observed exactly as in the red.

21 February.

10.30 a.m. *Red light.* Nearly every cell had sporulated.

Green light. No increase in the sporulation, and those which had not sporulated were becoming more and more empty looking.

Blue light. The cells were apparently breaking down and becoming disintegrated.

White light. No advance on the condition at 11 p.m. (20 February).

No light. Nearly every cell had sporulated.

The general results of the two preceding series of observations may be mentioned now, before proceeding to describe the remaining series.

(1) The cells developed in the dark did not advance in sporulation quite so quickly as in the others at the commencement, but arrived at completion at about the same time.

(2) The cells exposed to white light advanced at first more quickly than the cells in the dark, but not so quickly as in the red. The sporulation progressed up to a certain point and then stopped. An occasional dead cell, shown by staining, was noticed at the end of the experiment which was not noticed amongst the cells developed in the red and in the dark.

(3) In the green light the cells apparently began to sporulate at the same time as those incubated in the dark. But the

sporulation did not proceed very far: some cells formed perfect spores, and those which did not develope spores, appeared to degenerate.

(4) The cells developed in the blue and violet light appeared to show only very faint indications at the end of 29 hours; these indications disappeared later and the cells appeared to disintegrate.

In the following third series of observations, the gypsum blocks were seeded with pure cultures of Hansen's *S. Cerevisiæ I.*, *S. Ellipsoideus II.*, and *S. Pastorianus II.*, and the following notes describe the results.

27 February.

11 a.m. The gypsum blocks were seeded.

28 February.

10.30 a.m. *Red light.* Ellipsoideus shewed no indications of sporulation, except in one or two cells; Cerevisiæ shewed very faint indications; Pastorianus shewed no indications, except one or two cells.

Green light. No indications in Pastorianus and Ellipsoideus; very faint ones in Cerevisiæ, very similar to the red and no light.

Blue light. No indications at all in any of the three species.

White light. No indications in any of the species.

No light. Ellipsoideus and Cerevisiæ as in red.

3.30 p.m. *Red light.* Very faint indications in Ellipsoideus and Pastorianus; and some advance in Cerevisiæ.

Green light. Very faint indications in Ellipsoideus and slightly less than in red and no light.

Blue light. Indications as in white light.

White light. Doubtful indications in Cerevisiæ and Ellipsoideus; no indications in Pastorianus.

No light. Indications exactly as in the red.

10 p.m. *Red light.* Slight advance in the sporulation of Ellipsoideus and Cerevisiæ; and very slight in Pastorianus.

Green light. Ellipsoideus shewed indications as in red and no light; Cerevisiæ and Pastorianus were less advanced.

Blue light. No apparent advance, and cells were empty looking.

White light. Discarded through an accident.

No light. Indications very similar to those in the red.

The third series was not continued further as it was found on the morning of March 1st that the lamp was extinguished. It had probably gone out early in the preceding night. But the general results confirm the previous observations, although the distinctions which are not so well marked, were doubtless

due to the light being much less intense in this series of experiments. And besides that, the slow advance of the sporulation in the cells cultivated in the dark shewed that the cells were not very vigorous and healthy at the beginning.

The following notes describe the fourth series with pure cultures of *S. Cerevisiæ I.*

3 March.

11 a.m. The gypsum blocks were seeded.

4 March.

10.15 a.m. *Red light.* Most of the cells shewed indications of sporulation.
Green light. A few cells shewed doubtful indications.
Blue light. There were no indications whatever.
White light. Shewed indications as in red and no light.
No light. Shewed indications as in red.

2.45 p.m. *Red light.* Sporulation advanced since morning.
Green light. Hardly any advance.
Blue light. No indications whatever.
White light. Slightly less advanced than in the red and no light.
No light. Sporulation as in the red light.

7 p.m. *Red light.* Marked advance in sporulation.
Green light. Some advance, but the spores had an empty appearance. Not so advanced as in white light.
Blue light. A very few cells seem to be forming spores, but they were very empty looking, and other cells were deteriorating.
White light. Slightly less advanced than in red.
No light. Sporulation as in the red light.

The conclusions to be drawn from this fourth series of experiments confirm the previous series, viz.: (1) that the red rays appeared to act in the same way on the sporulation as when the yeast was left to sporulate in the dark, (2) that the green rays retarded the sporulation, and (3) that the blue and violet rays retarded the sporulation still more markedly. Only very vigorous and healthy cells seem to be able to sporulate under the influence of the blue and violet rays.

In the following fifth series an ordinary English brewery yeast was employed, and the observations were confined to the cultivations under the influence of no light, white light and green and blue lights.

17 March.

9.30 a.m. The gypsum blocks were seeded.

18 March.

9.30 a.m. *No light.* Cells granular; faint indications of spores.
White light. Faint indications of spores.
Green light. Faint indications, slightly less than in no light.
Blue light. Less marked indications of sporulation than in the green.

1.30 p.m. *No light.* Strong indications of spores.
White light. Indications in a few cells.
Green light. Not so far advanced in sporulation as in white light, and less than in no light.
Blue light. No advance on the observations at 9.30 a.m.

9.15 p.m. *No light.* Very slight advance on the observations at 1.30 p.m.
White light. The sporulation was nearly as far advanced as in no light.
Green light. Sporulation not so far advanced as in white light. The cells appeared to be more empty looking.
Blue light. Indications of spores were exceedingly slight; cells very empty looking.

19 March.

9.20 a.m. *No light.* Not examined.
White light. About 25 % of the cells had sporulated.
Green light. A certain number of the cells had developed; some of the unsporulated cells looked very empty; and the spores of others were very small.
Blue light. The development was not unlike that in the green; the spores were remarkably small, and the non-sporulated cells very empty looking.

5.30 p.m. *No light.* Well marked advance in sporulation; some of the cells had perfect spores.
White light. About 60—70 % of the cells had sporulated, and the remainder were very empty looking.
Green light. About 50 % of the cells sporulated; the rest were somewhat empty looking.
Blue light. Sporulation very similar to that in the green; the non-sporulated cells were very empty looking.

The results of these experiments with an ordinary English yeast are similar to the previous ones, viz.: that the rays of greater refrangibility interfered with the development of the spores, and that the green and blue rays influenced the retardation more than those of lower refrangibility.

A few experiments were conducted with the Cerevisiæ and Pastorianus species before-mentioned, by placing them within the influence of the ultra-violet rays. The light issued from an uncovered Welsbach mantle and played directly on the surface of the seeded gypsum blocks in one series, and through quartz

plates in another series. It appeared that the development of the spores was retarded still more than when they were under the influence of the blue and violet rays. And the general effect was to cause the cells to appear very thin and empty looking, as if they were breaking down.

Influence of radium. Finally the action of the emanations from radium was observed on four separate cultures of Cerevisiæ. The times of exposures were 15, 30 and 60 minutes and 30 hours respectively. The radium salt, kindly lent to us by Mr W. B. Hardy, was placed alternately over the seeded gypsum blocks. On examining the culture of 15 mins. exposure, the cells were granular; in the culture of 30 mins. exposure the cells were more marked in their granulations; whilst in that of 60 minutes the cells were very granular, and the contents of a few of the cells appeared to be escaping, due to the break-down of the cell wall. The granulation of the protoplasm of the cells of Saccharomyces is always a sure sign of starvation, decay, and old age, and it does not normally develope in so short a time as 15 minutes. In the culture of 30 hours exposure many of the cells appeared to have burst and the contents escaped. The cultures were afterwards incubated normally in order to develope spores. There appeared to be indications of spores here and there: but on inoculating sterilised wort from each of the growths, no fermentation or development of the cells was obtained. It appeared as if the radium emanations had destroyed the vitality of the cells.

General Conclusions.

The more important conclusions to be drawn from the preceding observations are: (1) the red rays or rays of low refrangibility accelerated the formation of spores more quickly than when the cells were incubated under the influence of white light; and they appeared to stimulate the activity of the sporulation more quickly than when the development took place in the dark, although in the latter case the sporulation seemed to be completed at about the same time as that in the red; (2) the green rays appeared to retard the development of the spores; (3) the blue and violet rays retarded the sporulation more markedly than the green rays; and (4) the ultra-violet rays were still more effective in the retardation, and they appeared to have the further effect of influencing detrimentally the vitality of the cells, when the latter were exposed to their influence for some time.

These facts may be explained chemically; for it is well known that the rays of high refrangibility have greater chemical energy than those of low refrangibility. It may be that the former instigate chemical changes within the cell antagonistic to the development of spores, whilst the latter, having much less chemical energy, have little or no influence, and the sporulation proceeds under healthier conditions. On the other hand, the retardation may be explained physically: for it may be that the vibratory motion of rays of high refrangibility shatters or neutralises that of the protoplasm of the cells which would result in the formation of spores, whilst the rays of low refrangibility are unable to exert such an influence.

The investigations will be continued and particularly with regard to the ultra-red and ultra-violet rays.

The influence of a strong magnetic field on the spark spectra of titanium, chromium and manganese. By J. E. Purvis, M.A., St John's College, Cambridge.

[*Read* 26 November 1906.]

The author has given accounts in previous communications of investigations on the influence of a magnetic field on the spark spectra of various metals*. The distances between the constituents of a considerable number of the divided spectral lines were measured, and the values of $d\lambda/\lambda^2$ were calculated therefrom. One of the results was to shew that some of the lines could be correlated and compared in possessing similar general appearances, similar corresponding constituents, and essentially identical values of $d\lambda/\lambda^2$ for these constituents.

The investigations of Runge and Paschen† testing and confirming Preston's Law shewed that the lines of different elements corresponding to the laws of series are separated in the same manner in the magnetic field and, as a check on the present series of observations, the author has repeated their experiments with several lines of the second subordinate series of magnesium, zinc and cadmium. The field strengths utilised by them varied between 28000 and 33000 C.G.S. units, and the spectra were produced simultaneously by passing the spark from one metal to the other. They claimed the advantage of thus avoiding the determination of the field strength, which cannot be made with the same relative accuracy as the measurements of the distances of the components. The only essential was to keep the field strength constant during an exposure, whilst the former might be different for different exposures. The following table, extracted from Runge and Paschen's paper (*Astrophysical Journal*, Vol. xv. p. 335), gives the distances of the components of the lines on the scale of vibration numbers; where, by the vibration number, is meant the number expressing the vibrations of light in passing over a distance of 1 cm. The distances were computed from the centre of gravity of the components, and are designated by the + sign when the components lie on the side of larger vibration numbers.

* *Trans. Camb. Phil. Soc.* Vol. xx. No. viii. p. 193; *Proc. Camb. Phil. Soc.* Vol. xiii. Pt vi. p. 325.

† *Astrophys. Journ.* Vol. xv. pp. 235, 333; Vol. xvi. p. 123.

	Mg.	Cd.
Mg. 5173 Cd. 4800 sextuplets	− 2·73	− 2·79
	− 2·16	− 2·14
	− 0·71	− 0·70
	+ 0·68	+ 0·70
	+ 2·07	+ 2·15
	+ 2·86	+ 2·79
Mg. 5168 Cd. 4678 triplets	− 2·82	− 2·82
	− 0·02	− 0·00
	+ 2·84	+ 2·82
Zn. 4722 Cd. 4800 sextuplets	− 2·65	− 2·68
	− 2·06	− 2·04
	− 0·67	− 0·67
	+ 0·67	+ 0·69
	+ 2·04	+ 2·04
	+ 2·66	+ 2·66
Zn. 4680 Cd. 4678 triplets	− 2·72	− 2·71
	0·00	0·00
	+ 2·72	+ 2·71

	Zn.
Mg. 5173 Zn. 4722 sextuplets	− 2·45
	− 1·90
	− 0·66
	+ 0·60
	+ 1·90
	+ 2·51
Mg. 5168 Zn. 4680 triplets	− 2·51
	− 0·01
	+ 2·52

In the author's experiments with these three metals, the spectrum of each metal was produced quite separately from the others by having both electrodes of the same metal, and the magnetic field was always of constant strength. The outside constituents of the sextuplets were not very clear of each other, and only by introducing a self-induction coil and using a very narrow slit was it possible to sharpen the lines so as to measure them with any degree of accuracy. They were more diffuse and weaker than the two middle constituents. In the sextuplets, the distances were measured between corresponding constituents; and in the triplets, from the centre of the middle one. The following table gives the values of $d\lambda/\lambda^2$ calculated from these measurements and in the same units as used by Runge and Paschen.

Zn. 4722	Mg. 5173	Cd. 4800	Mean	
+ 2·77	+ 2·78	+ 2·88	+ 2·81	*s*
+ 2·02	+ 2·06	+ 2·03	+ 2·04	*s*
+ 0·67	+ 0·68	+ 0·70	+ 0·68	*p*
0	0	0	0	
− 0·67	− 0·68	− 0·70	− 0·68	*p*
− 2·02	− 2·06	− 2·03	− 2·04	*s*
− 2·77	− 2·78	− 2·88	− 2·81	*s*

Zn. 4680·5	Mg. 5167·6	Cd. 4678·4	Mean	
+ 2·70	+ 2·75	+ 2·82	+ 2·75	*s*
0	0	0	0	*p*
− 2·72	− 2·74	− 2·82	− 2·76	*s*

These values are fairly comparable; and the ratio of the constituents of the sextuplets appears to be 1 : 3 : 4, whilst the values of the outside constituents of the triplets are comparable with the extreme constituents of the sextuplets. The numbers may be represented as simple multiples of 0·68, the index numbers being 1, 3 and 4.

The values of the constituents of the Cd. lines seem to be a little higher than the corresponding ones of Zn. and Mg., but the differences are probably due to errors in the measurements, and particularly as the extreme constituents of the sextuplets impinged so closely upon their neighbours that it was difficult to strike their centres of gravity.

The following notes describe the results of experiments with titanium, chromium and manganese. The same apparatus was used as in the experiments with the other metals. The strength of the field was 39,980 units, and only those lines were measured whose constituents left well marked images on the photographic plate during an exposure of 30 minutes.

The column λ gives the wave lengths of the lines; the distances between the constituents of the divided lines are omitted, but the values of $d\lambda/\lambda^2$ calculated from them are given, and a + sign means that the constituents are on the side of greater wave length and a − sign of shorter wave length. The letters *s* and *p* signify as before that the constituents vibrate so that their electric vectors are respectively perpendicular or parallel to the lines of force. The remark "the middle constituent removed by calcite" means that the constituents were so close, or intense or diffuse that they could only be seen separately by cutting out those parallel to the lines of force by introducing a calcite prism between the source of light and the condensing lens.

Titanium.

The lines were identified by comparison with the measurements and descriptions of Exner and Haschek (*Sitz. d. k. Akad. Wien*, Vol. CVII. II_A. Abth. p. 796) for wave lengths from 4747·83.

The line 3252·03 was divided into six constituents, which appeared to be equally sharp and strong. The measurements were taken between corresponding constituents. The values of $d\lambda/\lambda^2$ are in the simple ratio of 1 : 3 : 6.

λ	$d\lambda/\lambda^2$
	+2·82 *s*
	+1·40 *p*
	+0·47 *p*
3252·03	0
	−0·47 *p*
	−1·40 *p*
	−2·82 *s*

The following lines were divided into four constituents. They had not all the same appearance; several of them had the constituents equally sharp and strong, whilst of others the two outside constituents were weaker and more diffuse than the two inside ones.

λ	$d\lambda/\lambda^2$	
4314·98	+2·14 *s* +0·76 *p* 0 −0·76 *p* −2·14 *s*	The two outside constituents were weaker and more diffuse than the inside ones. Compare also 3072·17.
4302·18	+1·81 *s* +0·90 *p* 0 −0·90 *p* ?	The outside constituents were very weak and the most refrangible one widened into the triplet from 4301·30. The least refrangible was clear and distinct, but weak. The values of $d\lambda/\lambda^2$ are simple multiples of each other.
3388·00	+2·40 *s* +1·10 *p* 0 −1·10 *p* −2·40 *s*	The two outside constituents were weaker and more diffuse than the two inside ones. Also compare 3152·42.
3380·40	+2·27 *s* +1·19 *p* 0 −1·19 *p* −2·27 *s*	The two outside constituents were weaker and more diffuse than the two inside ones.
3321·85	+2·68 *s* +0·58 *p* 0 −0·58 *p* −2·68 *s*	The four constituents appeared to be equally sharp.
3315·47	+2·24 *s* +0·42 *p* 0 −0·42 *p* −2·22 *s*	The constituents appeared to be equally sharp and strong. There seems to be a simple numerical relationship between them.
3278·42	+2·67 *s* +1·21 *p* 0 −1·21 *p* −2·67 *s*	The two outside constituents were weaker and more diffuse than the two inside ones.
3272·23	+2·66 *s* +0·98 *p* 0 −0·98 *p* ? *s*	The most refrangible constituent widened into the quadruplet from 3271·80. The two middle constituents were strong and sharp.
3271·80	? *s* +0·78 *p* 0 −0·78 *p* −2·33 *s*	The least refrangible constituent widened into 3272·23; the two middle ones were not so strong as those of 3272·23. The constituents appeared to be simple multiples of each other.

λ	$d\lambda/\lambda^2$	
3236·25	+1·87 *s* +0·84 *p* 0 −0·84 *p* −1·87 *s*	The two outer constituents were weak and diffuse. The four appeared to be simple multiples of each other.
3152·42	+2·31 *s* +1·02 *p* 0 −1·02 *p* −2·31 *s*	The two outside constituents were weak and diffuse.
3117·80	+2·34 *s* +0·85 *p* 0 −0·85 *p* −2·34 *s*	The two outside constituents were very diffuse and weak.
3105·21	+2·05 *s* +0·68 *p* 0 −0·68 *p* −2·05 *s*	The two outside constituents were diffuse.
3072·17	+2·12 *s* +0·83 *p* 0 −0·83 *p* −2·12 *s*	The two outside constituents were weak and diffuse. Also compare 4314·98.

The two following lines were also divided into four, but the separate constituents were only seen distinctly by separating them by the calcite. The extreme constituents were weaker than the middle ones. The measurements were taken between corresponding constituents.

4706·41	+1·25 *s* +0·87 *p* 0 −0·87 *p* −1·25 *s*
4624·99	+1·83 *s* +1·15 *p* 0 −1·15 *p* −1·83 *s*

The following lines became triplets and the middle constituent was usually the strongest, but there were exceptions. In some cases the three constituents were equally strong. They also varied in the degree of their diffuseness; some were much more diffuse than others. As in other metals, the lines which were weakest normally had more widely separated constituents than the strong lines.

The middle constituent vibrated parallel, and the two outside ones perpendicular to the lines of force unless stated otherwise. The measurements of each triplet were from the centre of the middle constituent.

λ	$d\lambda/\lambda^2$	
5013·4	.....	The constituents were too weak to measure.
5006·7	+1·10 0 −1·10	The most refrangible constituent was very weak.
4998·9	+1·32 0 −1·32	
4990·4	+1·56 0 −1·57	
4981·1	+1·62 0 −1·63	
4840·1	.....	The constituents were too weak and diffuse to measure.
4804·4	.....	
4758·6	+1·53 0 −1·52	
4757·1	.....	do.
4682·12	+1·51 0 −1·53	
4667·80	+1·63 0 −1·65	
4656·70	.....	Too weak and too diffuse.
4617·50	+1·64 0 −1·64	
4572·24	+1·28 0 −1·29	
4564·0	+1·08 0 −1·09	
4555·71	+2·12 0 −2·12	

λ	$d\lambda/\lambda^2$	
	+2·14	
552·70	0	
	−2·15	
	+1·40	
549·90	0	
	−1·40	
	+ ?	
549·00	0	The least refrangible constituent widened into 4549·90.
	−2·26	
544·99	.....	The line became a broad diffuse band, in which no separation could be seen. On analysis by the calcite it appeared to divide into three broad and diffuse constituents too weak to measure.
536·22	.....	
535·79	.....	The constituents widened and blurred into one another, and it was difficult to isolate those corresponding to the respective lines.
535·00	.....	
534·23	.....	
533·50	.....	
527·57	.....	This line widened into a broad diffuse band like that of 4544·99. On analysis by the calcite it appeared to divide into three broad and diffuse constituents which were too weak to measure.
	+2·15	
523·06	0	
	−2·16	
	+2·20	
518·28	0	
	−2·18	
	+2·01	
513·00	0	
	−1·99	
	+1·21	
501·59	0	
	−1·19	
	+2·37	
496·40	0	
	−2·37	
	+1·58	
488·57	0	The constituents were very diffuse.
	−1·59	
	+2·24	
481·50	0	
	−2·25	
471·49	.....	Too weak and too diffuse to measure.
	+1·53	
438·79	0	
	−1·53	
	+2·14	
426·03	0	
	−2·15	

λ	$d\lambda/\lambda^2$	
4464·70	.....	The line widened into a broad diffuse band not unlike that of 4527·57, but not quite so wide. It was too weak to analyse.
	+1·81	
4457·70	0	
	−1·83	
	+1·68	
4455·59	0	
	−1·66	
4453·40	.....	The constituents of these two lines widened and blurred into each other.
4453·34	.....	
4451·15	.....	do.
4450·70	.....	
	+1·71	
4449·40	0	
	−1·73	
	+1·38	
4444·00	0	
	−1·37	
	+1·38	
4427·30	0	
	−1·36	
4421·98	.....	Too weak to measure the constituents.
4418·56	.....	The constituents widened and blurred into one another.
4417·95	.....	
4417·49	.....	
4411·30	.....	Too weak and diffuse to measure.
4404·52	.....	
	+1·93	
4400·02	0	
	1·94	
	+1·41	
4395·28	0	
	−1·40	
4394·14	.....	do.
4387·10	.....	
4375·05	.....	
	+1·24	
4367·89	0	
	−1·22	
4344·48	.....	do.
4341·57	.....	
	+1·07	
4338·10	0	
	−1·09	

λ	$d\lambda/\lambda^2$	
4321·89	+2·46 0 −2·47	
4318·83	.....	Too weak and too diffuse.
4316·92	.....	
4306·12	+1·64 0 −1·66	
4301·30	+1·75 0 −1·73	
4300·30	+1·63 0 1·65	
4294·30	+1·66 0 −1·66	
4291·11	+2·37 0 − ?	The most refrangible constituent widened into 4290·49.
4290·49	+1·36 0 −1·35	The three constituents seemed to be equally intense.
4288·00	.....	The constituents widened into one another, so that it was impossible to isolate them.
4287·60	.....	
4278·39	.....	The constituents of these lines were all too diffuse and weak to measure.
4274·80	.....	
4263·30	.....	
4186·30	.....	
4173·75	.....	
4172·15	+1·14 0 −1·15	
4163·90	+1·40 0 −1·41	
4082·59	.....	Too weak and too diffuse.
4078·57	+2·19 0 −2·23	
4065·22	.....	The constituents were all too weak and diffuse.
4064·39	.....	
4060·43	.....	
4055·18	.....	

λ	$d\lambda/\lambda^2$	
4054·00	+1·22 0 −1·25	
4028·50	+1·44 0 −1·46	
4025·32	+2·26 0 ?	The most refrangible constituent widened into the least refrangible of 4024·80.
4024·80	+ ? 0 −2·01	The least refrangible constituent widened into 4025·32.
4009·10	.....	Too diffuse and too weak.
3998·83	+1·79 0 −1·80	
3989·97	+1·49 0 −1·48	
3964·40 3963·00	....	do.
3958·37	+1·56 0 −1·58	
3956·49	+1·25 0 −1·25	The middle constituent was removed by calcite.
3948·84	+1·25 0 −1·25	do.
3947·90 3932·20	....	Too weak and too diffuse.
3913·69	+1·26 0 −1·25	
3904·98	+1·39 0 −1·40	
3900·72	+1·49 0 −1·47	
3883·00 3882·42	....	The constituents widened and blurred into one another.

λ	$d\lambda/\lambda^2$	
3875·42	.....	Too weak and too diffuse.
3836·19	+1·95 0 −1·93	
3828·40	.....	do.
3814·70	.....	
3813·49	.....	
3796·00	.....	
3786·13	+1·35 0 −1·35	The most refrangible constituent was very weak.
3776·19	+2·10 0 −2·10	do.
3771·80	+2·20 0 −2·21	
3762·00	+2·03 0 − ?	The most refrangible constituent widened into the least refrangible of 3761·42.
3761·42	+1·30 0 −1·27	
3759·42	+1·67 0 −1·64	
3757·82	+1·19 0 −1·19	The middle constituent was removed by calcite.
3753·80	.....	Too weak and diffuse, and widened into 3753·0.
3753·00	+1·75 0 −1·72	
3748·23	+1·28 0 −1·28	The middle constituent was removed by calcite.
3741·89	+1·62 0 −1·64	
3741·28	+ ? 0 −1·56	The least refrangible constituent widened into 3741·89.
3730·01	+0·98 0 −0·98	The middle constituent was removed by calcite.

λ	$d\lambda/\lambda^2$	
3725·32	.....	The constituents were all too weak and diffuse to measure.
3724·79	.....	
3722·72	.....	
	+2·26	
3721·80	0	
	−2·27	
3717·56	.....	Too weak and too diffuse to measure.
3710·11	.....	
3690·09	.....	
	+1·49	
3685·31	0	
	−1·46	
3669·10	.....	do.
	+1·22	
3662·39	0	
	−1·23	
3660·77	.....	do.
	+1·53	
3659·91	0	
	−1·54	
3654·70	.....	do.
	+1·60	
3653·64	0	
	−1·59	
	+1·46	
3642·87	0	
	−1·46	
	+1·44	The middle constituent was removed by calcite.
3641·50	0	
	−1·44	
	+1·09	
3635·62	0	
	−1·09	
3610·32	.....	Too weak to measure.
3598·86	.....	
3596·20	.....	
3593·22	.....	A very narrow triplet, and the calcite did not separate them sufficiently clear to measure the distances.
3573·89	.....	Triplet similar to that from 3593·22.
	+2·83	
3566·11	0	
	−2·82	

λ	$d\lambda/\lambda^2$	
3535·60	+1·56 0 −1·58	
3534·00	.....	Too weak to measure.
3520·47	.....	Triplet similar to that of 3593·22.
3511·00	+1·26 0 −1·26	
3510·00	.....	Too weak and too diffuse.
3505·90	+1·49 0 −1·50	
3491·26	+1·13 0 −1·13	
3477·39	+1·34 0 −1·36	
3465·70	.....	do.
3461·70	+1·43 0 −1·44	
3456·56	+1·84 0 −1·83	
3452·60	.....	The three constituents were very strong and very close, the calcite did not clearly separate them.
3444·53	+1·57 0 −1·55	
3402·61	+1·59 0 −1·56	
3388·90	+1·30 0 −1·29	The constituents were very diffuse.
3386·08	+1·73 0 −1·71	
3383·90	+1·00 0 −1·01	The middle constituent was removed by calcite, and the three constituents appeared to be equally strong.
3377·63	+1·50 0 −1·49	

λ	$d\lambda/\lambda^2$	
	+1·94	
3374·50	0	
	−1·95	
	+1·36	
3372·90	0	The three constituents appeared to be equally strong.
	−1·35	
	+1·70	
3371·60	0	
	−1·66	
3370·58	.....	Too weak and diffuse.
	+2·56	
3366·34	0	
	−2·54	
	+1·54	
3361·32	0	The three constituents were equally strong.
	−1·53	
	+1·54	
3354·80	0	
	−1·53	
3352·20	.....	Too weak and diffuse.
	+1·58	
3349·70	0	The three constituents were equally strong.
	−1·58	
		Exner and Haschek give one line at 3349·16, whilst Rowland gives three at 3349·043, 3349·135 and 3349·212. There are three lines well seen; a strong one at 3349·16 and two weaker ones, one on each side of this. The three constituents of 3349·16 are equally intense, and the least refrangible one widens into those of 3349·70. Also 3349·7 is reversed normally, whilst 3349·16 is not.
	?	
3349·16	0	
	−1·29	
	+2·23	
3346·92	0	
	−2·21	
	+2·09	
3343·92	0	
	−2·10	
	+1·28	
3341·99	0	The three constituents were equally strong.
	−1·30	
3337·97	.....	Too weak and too diffuse.
	+1·49	
3335·39	0	
	−1·50	
	+1·79	
3332·25	0	The constituents were very diffuse.
	−1·78	

λ	$d\lambda/\lambda^2$	
	+1·71	
3329·63	0	
	−1·72	
3326·92	.....	There appeared to be three overlapping wide and diffuse constituents; the middle one a little stronger than the others, and nearer to the least refrangible one than to the most refrangible. On analysis by the calcite the least refrangible constituent appeared to be wider than the most refrangible, but they were too weak and diffuse to measure.
	+1·81	
3323·05	0	
	−1·83	
	+2·18	
3318·20	0	
	−2·16	
3314·61	.....	Too weak and diffuse.
3309·62	.....	do.
	+2·10	
3308·99	0	
	−2·09	
3288·70	.....	
3288·57	.....	The constituents widened and blurred into one another.
3288·30	.....	
	+1·33	
3287·81	0	
	−1·32	
3280·17	.....	Too weak and diffuse.
	+1·95	
3279·07	0	
	−1·98	
	+1·76	
3277·10	0	
	−1·77	
3275·42	.....	do.
	+2·56	
3263·83	0	
	−2·54	
	+1·36	
3261·74	0	
	−1·34	
	+2·58	
3260·41	0	
	−2·59	
	+2·14	
3254·40	0	
	−2·17	

λ	$d\lambda/\lambda^2$	
3253·05	+2·00 0 −2·07	The most refrangible constituent was wider and more diffuse than either the middle one or the least refrangible.
3249·50	+2·24 0 ?	The most refrangible constituent widened into the least refrangible one of 3248·8.
3248·80	+1·65 0 −1·63	
3242·13	+0·55 0 −0·55	The middle constituent was removed by calcite.
3239·83	+1·77 0 −1·79	
3239·19	+1·47 0 −1·48	
3236·70	+1·78 0 −1·83	The three constituents were equally strong.
3234·63	+1·94 0 −1·91	do.
3232·50	+1·30 0 −1·31	
3231·48	+1·87 0 −1·88	The constituents were very weak.
3229·54	+1·51 0 −1·50	
3229·30	.....	The constituents widened into those of 3229·54 and were weak and diffuse.
3228·76	+1·20 0 −1·20	
3226·88	.....	Too weak to measure.
3224·43	+1·51 0 −1·51	
3223·00	+2·22 0 −2·23	

λ	$d\lambda/\lambda^2$	
	+1·37	
3218·43	0	
	−1·37	
	+2·15	
3217·20	0	
	−2·14	
	+1·99	
3214·90	0	The constituents were very weak.
	−1·99	
	+1·40	
3202·70	0	
	−1·40	
	+1·65	
3200·10	0	
	−1·64	
3197·64	.....	Too weak and diffuse to measure.
3195·83	.....	
	+1·46	
3192·20	0	
	−1·47	
	+1·54	
3191·02	0	
	−1·56	
	+1·31	
3186·60	0	The middle constituent was removed by calcite.
	−1·31	
	+1·66	
3168·69	0	
	−1·67	
3165·02	.....	Too weak and too diffuse to measure.
	+1·47	
3162·74	0	
	−1·49	
	+1·28	
3161·95	0	
	−1·29	
	+0·65	
3161·38	0	The middle constituent removed by calcite.
	−0·65	
	+1·70	The two outer constituents were sharper and stronger than the middle one which was very diffuse and at least as wide as the distance between the two outside ones. The two sharp ones vibrate parallel to the lines of force. The broad and diffuse middle constituent appeared to be further subdivided, but it was too weak to be distinguished accurately.
3154·34	0	
	−1·70	

λ	$d\lambda/\lambda^2$	
3143·88	+1·74 0 −1·77	
3130·91	+1·65 0 −1·65	The line widened into a broad band with faint appearances of division, and it was only by removing the middle constituent by the calcite that it appeared to be a triplet of three very diffuse bands of equally weak intensities.
3119·92	+2·16 0 −2·17	
3117·80	.....	The line widened into a broad band which shewed signs of division on analysis. The three constituents were all too weak to measure.
3112·19	+3·76 0 −3·78	The three constituents were very weak.
3110·81	+2·51 0 −2·49	
3110·21	.....	Too weak to measure.
3106·36	+2·25 0 −2·28	
3103·91	+1·50 0 −1·52	
3097·29	+2·08 0 −2·10	
3089·49	+1·31 0 −1·30	
3088·09	+1·58 0 −1·60	The three constituents were equally strong.
3078·70	+1·51 0 −1·53	do.
3075·30	+1·16 0 −1·15	
3071·37	+2·21 0 −2·22	
3059·86	+2·86 0 −2·88	The three constituents were very weak.

λ	$d\lambda/\lambda^2$	
	+2·18	
058·20	0	
	−2·21	
056·86	.....	The line widened into a broad band, which separated into three very weak and diffuse constituents when analysed by calcite; they were too weak and diffuse to measure.
	+2·00	
046·79	0	
	−2·02	
	+1·20	
⊬ ·84	0	
	−1·21	
	+1·40	
017·30	0	
	−1·39	
984·85	.....	The line separated into three very close constituents which were too diffuse to measure; and the calcite did not separate them sufficiently well to measure.
	+1·88	
956·26	0	
	−1·88	
948·40	.....	The constituents were all too weak and too diffuse to measure.
891·18	.....	
889·00	.....	
	+1·60	
884·22	0	
	−1·61	
	+1·33	
877·52	0	
	−1·35	
	+1·38	
862·47	0	
	−1·40	
856·22	.....	Too weak and too diffuse to measure.
851·21	.....	Too narrow and diffuse to measure, and on separation by calcite it was too weak.
	+1·52	
842·01	0	
	−1·54	
832·24	.....	do.

There were other lines which became triplets in the more refrangible regions beyond 2832·24, but they were all too weak and too diffuse to measure exactly.

The spectrum of titanium has a number of lines more like diffuse bands, which, generally, are sharp on the more refrangible edges and diffuse and weak on the less refrangible. They appeared

to become weaker, sharper and narrower, and the strongest of them seemed to be divided into very diffuse triplets. On the other hand, there are four band-like lines 4649·8, 4643·6, 4620·9, and 4444·7 which were widened but were too weak to analyse.

There were numerous other lines which appeared to be divided or widened, but they were not sufficiently strong to measure; whilst the lines 4295·94, 3340·53, and 3073·03 did not appear to be either widened or divided; they became a little sharper and weaker.

The following lines were divided into two. The two constituents were generally very weak, and their appearance was of two lines the outside edges of which were more diffuse than the inside. On analysis, some of them divided into quadruplets, but they were too weak to measure exactly. In the other instances, also, they were probably made up of several constituents. The measurements were taken between the centres of the aggregates. It will be noticed that there are some of these doublets which have the same value of $d\lambda/\lambda^2$, and the general appearance of the divided lines is also very similar.

λ	$d\lambda/\lambda^2$	
4779·10	+1·18 0 −1·18	The outside edges were more diffuse than the inside edges.
4590·20	+1·15 0 −1·15	do.
4529·73	+1·29 0 −1·29	do.
4315·70	+1·74 0 −1·74	The constituents were equally sharp in both edges.
4298·88	+0·72 0 −0·72	The outer edges more diffuse than the inside edges.
4289·25	+1·38 0 −1·38	The constituents were equally sharp in both edges.
4286·20	+1·32 0 −1·32	The outer edges more diffuse than the inside edges.
4012·58	+0·81 0 −0·81	Both constituents very diffuse.

λ	$d\lambda/\lambda^2$	
3981·99	+0·78 0 −0·78	Most probably a quadruplet, with the two outside constituents impinging closely upon the two middle ones. The line 3982·6 widened into it and interfered with correct measurement.
3930·00	+1·39 0 −1·39	Both constituents were very diffuse.
3924·70	+1·28 0 −1·28	Both constituents were diffuse on the outside edges.
3921·59	.....	Too weak to measure.
3679·88	+1·15 0 −1·15	Diffuse on the outside edges; appeared to be a quadruplet; too weak to measure the four separated constituents.
3671·81	+1·29 0 −1·29	do.
3658·21	+1·13 0 −1·13	do.
3644·88	.....	Too weak to measure.
3587·20	+1·33 0 −1·33	Diffuse on the outside edges, and appeared to be a quadruplet; too weak to measure the separated constituents.
3561·71	+1·68 0 −1·68	do.
3500·51	+1·34 0 −1·34	do.
3489·91	+1·44 0 −1·44	do.
3282·50	+1·91 0 −1·91	The edges of the constituents were equally sharp.
3174·91	.....	Too weak to measure.
3155·81	+0·50 0 −0·50	Diffuse on the outer edges of the constituents, and appeared to be further divided, but it was too weak to distinguish on analysis.
3148·13	+0·87 0 −0·87	Diffuse on the outside edges; appeared to be a quadruplet with the constituents overlapping, but on analysis they were too weak for measurement.
2868·81	+1·28 0 −1·28	The outside edges diffuse.

General results of Titanium.

The more important results of the preceding observations are:—

1. There were several types in the appearances of the divided lines. Some of the lines separated into diffuse constituents whilst others were sharp and well defined. Amongst the triplets the general rule was that the middle constituent was at least twice as strong as either of the others; but there were several having the three constituents almost equally strong. Also there were several which had two sharp and strong outside constituents whilst the middle one was weak and diffuse.

2. The line 3252·03 divided into six constituents, and the values of $d\lambda/\lambda^2$ appear to have the simple ratio 1 : 3 : 6. Amongst the lines which divided into four constituents there are several whose values of $d\lambda/\lambda^2$ are simple multiples of one another, and there are several which can be compared together in having identical values of $d\lambda/\lambda^2$, and this comparison extends to their appearance and their polarisation.

3. Amongst the lines which became triplets, there are some which can be compared in a similar way. And also the values of $d\lambda/\lambda^2$ for the constituents of some lines are simple multiples of those of other lines.

4. There were a number of lines, very like bands, sharper on the more refrangible edges and diffuse and weak on the less refrangible. These became sharper and narrower, and the strongest of them were divided into somewhat diffuse triplets. There were several weak band-like lines which were widened, but no division could be seen, and they were too weak to shew anything on the plate when analysed by the calcite.

5. The constituents of the strongest and most intense lines were not usually separated farthest apart. Amongst the triplets the weaker lines usually gave higher values of $d\lambda$; corresponding to similar observations of the divided lines of other metals investigated.

Chromium.

The lines were identified and compared with the measurements and descriptions of Exner and Haschek (*Sitz. d. k. Akad. Wien*, 1897, Vol. CVI. II_A. Abth. p. 1133). The divided lines of chromium shewed many different types; and in most of the elements hitherto observed, the number of constituents was usually greater amongst the lines of smaller refrangibility, whilst in chromium there are a number of lines of high refrangibility which have more than three constituents easily separated from each other.

The line 2866·8 appeared to be divided into eight constituents; there were two stronger ones vibrating parallel, and six weaker ones perpendicular, to the lines of force, but the constituents were seen clear only by separating them by the calcite prism. The following gives the values of the measurements between corresponding constituents.

λ	$d\lambda/\lambda^2$	
2866·80	+3·16 *s*	The measurements were taken between corresponding constituents. The two constituents vibrating parallel to the lines of force were much stronger than those vibrating perpendicular; but they themselves were equally strong. Of the six constituents vibrating perpendicular, the middle one of each group of three was stronger than the other two; but both groups of three were the same in intensity and diffuseness. There appears to be a simple numerical relationship between the eight constituents.
	+2·03 *s*	
	+1·65 *p*	
	+0·92 *s*	
	0	
	−0·92 *s*	
	−1·65 *p*	
	−2·03 *s*	
	−3·16 *s*	

The following lines were divided into six constituents which were seen clearly separate only by use of the calcite. The measurements were taken between corresponding constituents.

3147·23	+2·32 *s*	The two constituents vibrating parallel were sharper and stronger than the others, and the two extreme outside ones were very weak. They appear to be simple multiples of one another.
	+1·62 *s*	
	+0·75 *p*	
	0	
	−0·75 *p*	
	−1·62 *s*	
	−2·32 *s*	
2855·73	+2·14 *s*	The two constituents vibrating parallel were broad and strong, and not easily separated; whilst the two extreme outside ones vibrating perpendicular were very weak and impinge upon the adjoining ones.
	+0·85 *s*	
	+0·64 *p*	
	0	
	−0·64 *p*	
	−0·85 *s*	
	−2·14 *s*	
2757·75	+2·11 *s*	do.
	+0·85 *s*	
	+0·67 *p*	
	0	
	−0·67 *p*	
	−0·85 *s*	
	−2·11 *s*	

The line 2861·01 was divided into five constituents, and the measurements were taken from the centre of the middle one.

2861·01	+3·30 *s*	The three middle constituents were stronger than the two outside ones, and the innermost was slightly stronger than the other two; the two extreme ones were very weak and almost impinged upon the outer edges of the two vibrating parallel to the lines of force. There appears to be a simple numerical relation between them.
	+1·70 *p*	
	0 *s*	
	−1·71 *p*	
	−3·31 *s*	

The following lines were divided into four constituents, and the differences in their general appearances are noted. The measurements were between corresponding constituents, and for several of them there appears to be a simple ratio between the values of $d\lambda/\lambda^2$.

λ	$d\lambda/\lambda^2$	
3403·47	+2·46 *s* +1·26 *p* 0 −1·26 *p* −2·46 *s*	The two outside constituents were weaker and more diffuse than the two inner ones.
3382·82	+2·43 *s* +0·82 *p* 0 −0·82 *p* −2·43 *s*	do.
3342·78	+2·28 *s* +0·86 *p* 0 −0·86 *p* −2·28 *s*	do.
3340·03	+2·68 *s* +1·30 *p* 0 −1·30 *p* −2·68 *s*	do.
3209·3	+2·20 *s* +0·77 *p* 0 −0·77 *s* −2·21 *p*	The third constituent, counting from the less refrangible end, was stronger than the second, and the fourth was a little stronger than the first. The polarised condition of the four constituents is abnormal.
3136·81	+1·30 *s* +1·16 *p* 0 −1·16 *p* −1·30 *s*	The two outside constituents were weaker and more diffuse than the two inner ones.
2865·22	+2·09 *s* +1·08 *p* 0 −1·08 *p* −2·09 *s*	do.
2862·62	+2·07 *s* +0·79 *p* 0 −0·79 *p* −2·07 *s*	do.

λ	$d\lambda/\lambda^2$	
59·00	+2·37 *s* +0·85 *p* 0 −0·85 *p* −2·37 *s*	The four constituents were sharp and narrow, and the two middle ones were only a little stronger than the two extreme ones.
51·91	+1·26 *s* +0·32 *p* 0 −0·32 *p* −1·26 *s*	do.
50·78	+2·60 *s* +0·83 *p* 0 −0·83 *p* −2·60 *s*	The middle constituents were stronger than the two extreme ones, but they were all equally sharp.
49·01	+3·38 *s* +1·18 *p* 0 −1·18 *p* −3·39 *s*	The two middle constituents only a little stronger than the two extreme ones.
43·67	+2·87 *s* +0·72 *p* 0 −0·72 *p* −2·88 *s*	do.

The following lines were divided into four constituents, but ıe separation was only clearly marked on analysis by the calcite.

33·5	+1·16 *p* +0·81 *s* 0 −0·81 *s* −1·16 *p*	There were traces of other constituents, one on each outer side of those vibrating parallel to the lines of force: they were very weak and were quite invisible on interposing the calcite. The polarised condition of the constituents is to be noted.
22·92	+1·19 *s* +0·62 *p* 0 −0·62 *p* −1·19 *s*	The two extreme constituents were weaker and more diffuse than the two middle ones. Compare 3358·64.
58·64	+1·15 *s* +0·57 *p* 0 −0·57 *p* −1·15 *s*	do.
97·22	+1·14 *s* +1·01 *p* – −1·01 *p* −1·14 *s*	The second and the fourth constituent, counting from the less refrangible end, were stronger than the first and third.

The following lines were divided into triplets. The middle constituent was usually the strongest; but there were exceptions to this. In some instances the three constituents were equally strong; and in others, the middle constituent was very little stronger than the other two. The constituents also varied in their relative diffuseness; some were sharp and clear, whilst others were very diffuse. Unless otherwise stated, the middle constituent vibrated parallel, and the two outside ones perpendicular, to the lines of force.

λ	$d\lambda/\lambda^2$	
4652·34	.....	The constituents were too weak to measure.
4646·35	+1·57 0 −1·56	There appeared to be a division of the middle constituent: but it was not very clear.
4642·20	.....	The constituents were too weak to measure.
4639·77	.....	
4626·35	.....	
4588·42	.....	
4558·90	+1·54 0 −1·56	
4351·99	+1·57 0 −1·59	
4344·73	+1·48 0 −1·50	
4339·69	+0·81 0 −0·81	Middle constituent removed by calcite.
4337·78	.....	Too weak to measure.
4289·92	+2·26 0 −2·26	The middle constituent was very little stronger than the two outside ones; and the latter were more diffuse on the outside edges than on the inside edges.
4274·99	+2·80 0 −2·81	The middle constituent was very little stronger than the two outside ones.
4254·50	+1·83 0 −1·83	Middle constituent was removed by calcite; the three constituents widened into one another, and the outer edges of the two outside constituents were more diffuse than the inner edges.
3984·08	.....	Constituents too weak to measure.

λ	$d\lambda/\lambda^2$	
3963·86	+1·65 0 −1·65	Middle constituent removed by calcite. The most refrangible constituent was wider and more diffuse than the least refrangible one.
3919·32	+2·16 0 −2·19	
3908·90	+2·32 0 −2·34	The middle constituent was very little stronger than the two outside ones.
3749·18 3748·81	....	The constituents widened and blurred into one another.
3605·47	+2·21 0 −2·18	
3593·64	+2·68 0 −2·63	The middle constituent was very little stronger than the two outside ones.
3578·83	+1·43 0 −1·43	Middle constituent removed by calcite. The three constituents were very diffuse
3408·91	+1·66 0 −1·67	
3394·72	+1·48 0 −1·48	The *two outside* constituents were sharp and strong and the middle constituent was weak and diffuse. Also the two outside constituents vibrated parallel to the line of force and the middle one perpendicular thereto.
3394·49	+1·84 0 −1·81	
3394·00	+1·70 0 −1·73	
3379·99	+2·00 0 −2·02	The middle and the most refrangible constituent were both stronger than the least refrangible one.
3379·50	.....	Too weak to measure and widened into the triplet from 3379·99.
3378·49	+1·99 0 −2·00	
3368·20	+1·65 0 −1·66	The constituents were very diffuse.
3367·20	.....	Too weak to measure.

λ	$d\lambda/\lambda^2$	
	+2·08	
3361·92	0	
	−2·08	
	+2·02	
3360·48	0	
	−2·03	
	+1·75	
3357·52	0	
	−1·73	
	+1·42	
3348·00	0	The three constituents were diffuse.
	−1·39	
	+1·53	
3335·52	0	The three constituents were very diffuse.
	−1·51	
3328·50	.....	Too weak to measure.
	+1·70	
3324·52	0	
	− ?	The most refrangible constituent of 3324·52 widened into the least refrangible one of 3324·27.
	+ ?	
3324·27	0	
	−1·47	
3312·35	.....	The constituents widened and blurred into each other; and it was impossible to isolate them.
3312·10	.....	
3310·86	.....	Too weak to measure.
3308·31	.....	
	+1·44	
3307·20	0	The three constituents were very diffuse.
	−1·40	
	+1·53	
3295·58	0	The three constituents were very sharp.
	−1·56	
3270·28	.....	
3264·40	.....	Too weak and diffuse to measure.
3258·88	.....	
	+1·46	
3238·90	0	
	−1·48	The constituents were very diffuse.
	+1·40	
3234·20	0	
	−1·37	
	+0·90	
3217·51	0	The middle constituent was removed by calcite.
	−0·90	

λ	$d\lambda/\lambda^2$	
3216·61	.....	Too weak to measure.
3183·44	+1·24 0 −1·20	The constituents were very diffuse.
3181·57	.....	Too weak to measure.
3180·82	+1·53 0 −1·50	The most refrangible constituent was not so strong as the least refrangible one.
3172·20	.....	Too weak to measure.
3169·31	.....	
3152·34	+1·77 0 −1·73	The most refrangible constituent was not so strong as the least refrangible one.
3140·26	.....	Too weak to measure.
3135·86	+1·79 0 −1·77	
3135·46	.....	Too weak and widened into 3135·86.
3134·43	.....	Too weak to measure.
3132·20	+1·83 0 −1·81	The middle constituent was very little stronger than the two outside ones.
3128·82	+1·76 0 −1·76	The general appearance of this triplet was quite different from the others: it had two outer sharp and strong constituents, and a broad diffuse weak middle one; the width of the latter was as great as the distance between the two outside ones. The two strong constituents vibrated parallel to the lines of force, and the middle one perpendicular thereto.
3125·12	+1·61 0 −1·59	
3122·73	+1·94 0 −1·93	
3120·50	+1·30 0 −1·28	
3118·78	+0·67 0 −0·67	The middle constituent was removed by calcite, and was very little stronger than the two outside ones.
3116·86	.....	Too weak to measure.
3115·77	.....	
3107·70	+1·93 0 −1·95	

λ	$d\lambda/\lambda^2$	
3103·60	.....	Too weak to measure.
3096·27	.....	
3095·65	.....	
3094·12	.....	
	+1·64	
3093·61	0	
	−1·63	
3077·89	.....	do.
3077·39	.....	
3055·57	.....	
3054·00	.....	
	+1·48	
3050·23	0	
	−1·50	
3047·90	.....	The constituents widened and blurred into each other.
3047·77	.....	
	+1·47	The three constituents were very diffuse.
3041·85	0	
	−1·46	
	+1·32	do.
3041·03	0	
	−1·32	
	+1·23	do.
3028·22	0	
	−1·23	
	+1·58	do.
3026·78	0	
	−1·58	
	+2·01	
3024·46	0	
	−2·02	
	+1·70	
3021·68	0	
	−1·71	
	+2·12	
3020·77	0	
	−2·10	
3018·91	.....	Too weak for analysis.
3018·59	.....	
	+1·59	
3017·66	0	
	−1·60	
	+1·57	
3015·58	0	
	−1·59	

λ	$d\lambda/\lambda^2$	
3015·30	.....	Widened into 3015·58 and impossible to isolate the constituents.
3014·88	.....	Too weak and widened into the doublet from 3015·05.
3013·16	.....	Too weak to measure.
3005·16	+2·34 0 −2·36	
3003·98	.....	Too weak and too diffuse to measure.
3000·04	+2·08 0 −2·06	
2996·69	.....	Too weak to measure.
2989·25	+0·98 0 −0·98	The middle constituent was removed by calcite.
2988·75	.....	Too weak to measure.
2988·13	.....	
2986·52	+2·17 0 −2·16	
2986·10	+ ? 0 −1·98	The least refrangible constituent widened into the triplet from 2986·52.
2985·40	+1·48 0 −1·49	
2979·80	+1·63 0 −1·64	
2976·90	.....	Too weak to measure.
2975·59	.....	
2971·99	+1·77 0 −1·78	
2966·14	+1·58 0 −1·59	
2953·79	+1·44 0 − ?	The most refrangible constituent widened into the doublet from 2953·46.
2947·60	.....	Too weak to measure.

λ	$d\lambda/\lambda^2$	
2946·93	+1·44 0 −1·45	
2942·08	+1·45 0 −1·45	
2940·34	+1·25 0 −1·26	
2939·46	....	Too weak to measure.
2935·22	+1·76 0 −1·75	
2934·07	+0·96 0 −0·96	The middle constituent was removed by calcite.
2928·42	+1·16 0 −1·16	do.
2928·28	.....	Too weak and widened into the triplet of 2928·42.
2927·19	+1·66 0 −1·69	
2923·80	+1·41 0 −1·41	The middle constituent was removed by calcite.
2923·57	.....	Too weak and widened into the triplet from 2923·80.
2921·92	+1·15 0 −1·15	Middle constituent removed by calcite.
2921·32	+1·33 0 −1·33	do.
2915·58 2915·34	....	The constituents widened into each other, and they were too weak to separate by the calcite.
2911·78 2910·73 2904·16	....	Too weak to measure.
2899·58	+2·02 0 −2·01	
2899·26	.....	do.

λ	$d\lambda/\lambda^2$	
	+1·68	
2898·60	0	
	−1·69	
	+1·80	
2897·79	0	
	−1·82	
2896·85	.....	Too weak to measure.
	+1·71	
2896·56	0	
	−1·69	
2891·28	.....	The constituents widened and blurred into one another, so that it was impossible to measure them.
2891·13	.....	
	+1·71	
2889·96	0	The most refrangible constituent widened into the triplet of 2889·59.
	− ?	
2889·59	.....	
2889·26	.....	The constituents widened and blurred into one another.
2888·81	.....	
2887·87	.....	The constituents are too weak to measure.
2881·99	.....	
	+1·91	
2880·95	0	
	−1·90	
	+2·76	
2878·52	0	
	− ?	The most refrangible constituent of 2878·52 widened into the least refrangible one of 2878·03 and it was impossible to isolate them.
	+ ?	
2878·03	0	
	−2·70	
2876·37	.....	Widened into a band, and no clear and definite separation.
	+2·14	
2876·07	0	
	−2·15	
	+1·46	
2873·91	0	The appearance of the triplet was not unlike that of 3128·82, i.e. there were two sharp and strong constituents on the outside, and an inside broad and weak one.
	−1·46	
	+ ?	
2873·57	0	The least refrangible constituent coincided with the constituents of 2873·91 and it was impossible to separate them.
	−2·72	
2871·55	.....	Too weak to measure.
	+1·81	
2870·51	0	
	−1·82	

λ	$d\lambda/\lambda^2$	
2857·49	+2·14 0 −2·12	
2856·85	+2·20 0 −2·20	
2855·13	+1·08 0 −1·08	The middle constituent was removed by calcite.
2853·30	.....	Too weak to measure.
2851·41	+1·25 0 −1·25	The middle constituent was removed by calcite.
2849·98	+1·27 0 −1·27	do. The two outside constituents appeared to be more diffuse on the outside edges than on the inside edges.
2846·51	.....	Too weak to measure.
2843·35	+1·67 0 −1·67	The middle constituent was removed by calcite.
2840·10	+1·39 0 −1·39	do.
2838·87	+1·97 0 −2·00	
2836·55	.....	Too weak to measure.
2835·75	+1·80 0 −1·80	The middle constituent was removed by calcite.
2834·83	+1·37 0 −1·37	do.
2832·54	+1·48 0 −1·48	do.
2830·57	+1·58 0 −1·57	
2822·47	+1·57 0 −1·58	

λ	$d\lambda/\lambda^2$	
2822·10	+1·15 0 −1·15	The middle constituent was removed by calcite.
2818·42	+1·26 0 −1·26	do.
2816·89	.....	Too weak to measure.
2812·03	+1·39 0 −1·40	
2800·81	+0·82 0 −0·82	
2792·20	+1·72 0 −1·70	
2789·43	.....	do.
2787·67	+2·43 0 −2·41	
2785·73	+1·33 0 −1·33	The middle constituent was removed by calcite.
2782·42 2781·17	....	Too weak to measure, and the constituents blurred into one another.
2780·35	+1·07 0 −1·07	The middle constituent was removed by calcite.
2778·11	+1·48 0 −1·48	do.
2768·65	+1·31 0 −1·31	do.
2766·61	+1·80 0 −1·80	do.
2765·96	.....	Too weak to measure.
2762·70	+1·47 0 −1·47	The middle constituent was removed by calcite; it was broad and strong and the outside edges of the two outside constituents were a little more diffuse than the inside edges.
2759·46	+1·65 0 −1·65	The middle constituent was removed by calcite.

λ	$d\lambda/\lambda^2$	
2759·02	.....	Too weak to measure.
2746·23	.....	
	+2·63	
2742·12	0	
	−2·66	
	+2·52	
2740·13	0	
	−2·54	
2727·81	.....	do.
2724·11	.....	
2722·82	.....	
	+2·35	
2712·39	0	
	−2·34	
2711·00	.....	do.
2709·49	.....	
2708·88	.....	
	+1·56	
2703·65	0	
	−1·57	
2698·72	.....	The constituents widened and blurred into one another, and it was impossible to isolate them.
2698·49	.....	
2698·00	.....	
2693·62	.....	Too weak to measure.
	+2·20	
2691·15	0	
	−2·20	
2688·34	.....	do.
	+2·44	
2687·19	0	
	−2·41	
	+2·19	
2678·88	0	
	−2·21	
	+2·23	
2677·31	0	
	−2·23	
	+2·01	
2672·91	0	
	−2·00	
	+2·14	There seemed to be some appearance of a division of the middle broad constituent, but it was not very distinct.
2671·90	0	
	−2·14	

λ	$d\lambda/\lambda^2$	
	+2·12	
2666·12	0	
	−2·12	
	+2·10	
2663·45	0	
	−2·07	
	+2·00	
2653·63	0	
	−2·01	

The lines in the ultra-violet beyond 2653·63 were very weak, and there was very little to be seen on the photographic plate. Several of them were noted, but they were too weak to measure; such are :—

2608·01	.....	All too weak for analysis.
2590·88	.....	
2563·71	.....	
2533·50	.....	
2530·06	.....	

There were also many other lines which were divided or widened, but they were too weak to measure. Only those lines are described which clearly affect the photographic plate during an exposure of 30 minutes.

The lines 3991·31 and 2953·46 were neither widened nor divided; they appeared to become a little sharper.

The following were divided into two, but the constituents had not all the same appearance. In some of them the outside edges were more diffuse than the inside edges, and it is probable they were quadruplets not unlike those described on p. 65, but they were too weak to measure on analysis by the calcite. In others, there did not appear to be any difference in the diffuseness of the edges; but they also may be aggregates of several constituents. The measurements were taken between the centres of the aggregates.

	+0·47	
3991·31	0	
	−0·47	
	+2·07	The outside edges of the constituents were more diffuse than the inside ones.
3976·82	0	
	−2·07	
	+0·91	Too weak to analyse.
3969·93	0	
	−0·91	

λ	$d\lambda/\lambda^2$	
3713·40	+1·44 0 −1·44	The outside edges of the constituents were more diffuse than the inside ones.
3678·05	+1·50 0 −1·50	do.
3631·86	+1·01 0 −1·01	The edges of the two constituents appeared to be equally sharp on both sides.
3603·90	+1·46 0 −1·46	The constituents were very diffuse.
3585·48	+1·03 0 −1·03	The edges of the constituents were equally sharp on both sides.
3421·4	+2·06 0 −2·06	The constituents were equally sharp on both edges.
3336·49	+2·30 0 −2·30	
3291·96	+1·32 0 −1·32	The outside edges of the two constituents were more diffuse than the inside ones.
3030·37	+1·10 0 −1·10	do.
3015·05	+0·88 0 −0·88	
2961·81	+1·32 0 −1·32	do.
2953·46	+2·04 0 −2·04	The appearance of the two constituents was like that of 3421·4 and 3336·49.
2937·04	.....	Too weak to measure.
2932·81	+1·34 0 −1·34	All these constituents were very weak and diffuse.
2930·96	+1·05 0 −1·05	
2894·33	+1·24 0 −1·24	

λ	$d\lambda/\lambda^2$	
2867·70	+2·36 0 −2·36	The two constituents were equally sharp and strong. They were very similar to those of 3336·49.
2668·78	+1·28 0 −1·28	The constituents of these appeared to be equally sharp on both sides.
2658·65	+1·25 0 −1·25	

Manganese.

The lines were identified by reference to the measurements of Exner and Haschek (*Sitz. d. k. Akad. Wien*, vol. CV. II_A. Abth. p. 399, and vol. CIV. II_A. Abth. p. 921). The constituents of the divided lines were much more diffuse than in other metals. The rapid oxidation of the metal also caused the spark to be irregular and this may have increased the diffuseness.

The following lines were divided into four constituents, but the outside constituents of 3488·8 and 3482·9 were too weak and diffuse to measure. It will be noticed that the constituents of 3473·9 are simple multiples of each other.

	? *s*	
	+1·65 *p*	
3488·8	0	
	−1·65 *p*	
	? *s*	
	? *s*	
	+0·87 *p*	The two outside constituents were very weak and diffuse and impinge upon the two inside strong and sharp ones.
3482·9	0	
	−0·87 *p*	
	? *s*	
	+3·13 *s*	
	−1·51 *p*	The most refrangible constituent was weaker than the other three; and the two middle ones were the strongest. They were all very diffuse.
3473·9	0	
	−1·51 *p*	
	−3·13 *s*	

The following lines were divided into triplets. The middle constituent was usually the strongest, and in some instances the two outside constituents were exceedingly weak as compared with the strong intense middle one. The middle constituent vibrated parallel, and the two outside ones perpendicular to the lines of force.

λ	$d\lambda/\lambda^2$	
4823·9	.....	Too weak to measure.
4783·6	+2·71 0 −2·70	Compare λλ 4033·1 and 2939·3.
4766·6	.....	The constituents of these lines widened and blurred into each other.
4766·0	.....	
4762·5	+1·81 0 −1·82	The middle constituent of both these triplets was much stronger than the two outside constituents.
4754·2	+2·26 0 −2·27	
4464·8	+2·22 0 −2·24	
4462·3	.....	Too weak to measure.
4451·5	+2·15 0 −2·13	
4235·2	+1·60 0 −1·60	The middle constituent was removed by calcite.
4083·8	+2·56 0 −2·56	The middle constituent of each of these triplets was removed by calcite. The constituents were wide and diffuse.
4083·0	+2·56 0 −2·56	
4079·3	+2·16 0 −2·16	
4055·5	+2·25 0 −2·24	
4048·8	+2·10 0 −2·10	The middle constituent was removed by calcite. The three constituents were much more diffuse than those from 4055·5.
4041·5	+2·16 0 −2·18	
4035·9	+2·18 0 −2·16	The three constituents were much more diffuse than those from 4041·5, 4034·5, and 4033·1. Compare 4018·4.

λ	$d\lambda/\lambda^2$	
4034·5	+2·46 0 −2·46	
4033·1	+2·72 0 −2·73	Compare λ 4783·6.
4030·9	+1·96 0 −1·96	The middle constituent was removed by calcite.
4018·4	+2·05 0 −2·03	Compare λ 4035·9.
3823·5	+1·38 0 −1·38	The middle constituent was removed by calcite.
3806·8	+1·66 0 −1·66	do.
3586·7 3578·0 3497·6	....	The constituents of these triplets were too weak to measure.
3496·0	+3·31 0 −3·30	
3441·8	+1·64 0 −1·61	
3273·9	.....	Too weak to measure.
3248·4	+1·50 0 −1·50	The middle constituent was removed by calcite.
3236·8	.....	Too weak to measure.
3228·2	+1·56 0 −1·56	
3035·5 3031·0 2951·4	....	The constituents were too weak to measure.
2949·3	+1·46 0 −1·46	The middle constituent was removed by calcite.
2939·3	+2·70 0 −2·72	Compare λλ 4783·6 and 4033·1.

λ	$d\lambda/\lambda^2$	
	+2·37	
2933·1	0	
	−2·38	
2900·3	.....	Too weak to measure.
2898·8	.....	
	+1·15	The middle constituent of each of these triplets was removed by calcite.
2892·6	0	
	−1·15	
	+1·47	
2889·8	0	
	−1·47	
2887·1	.....	Too weak to measure.
	+1·48	The middle constituent was removed by calcite.
2879·7	0	
	−1·48	
2873·0	.....	Too weak to measure.
2870·2	.....	
2812·6	.....	
	+2·34	The middle constituent of each triplet was removed by calcite.
2801·0	0	
	−2·34	
	+2·40	
2798·3	0	
	−2·40	
2795·2	.....	The constituents widened and blurred into one another.
2794·9	.....	
2711·5	.....	Too weak to measure.
2710·1	.....	
2708·3	.....	
2705·7	.....	
	+1·36	The middle constituent was removed by calcite.
2701·3	0	
	−1·36	
2688·8	.....	The constituents of all these triplets were too weak to measure.
2672·8	.....	
2640·0	.....	
2632·3	.....	
2625·6	.....	
2618·2	.....	
2610·3	.....	
	+1·93	The middle constituent was removed by calcite.
2605·8	0	
	−1·93	
	+2·45	
2593·8	0	
	−2·45	
2563·8	.....	The constituents were too weak to measure.
2558·6	.....	

The following lines were divided into two. They were all very diffuse, and it was impossible to distinguish if there was any further separation.

λ	$d\lambda/\lambda^2$	
4059·0	+1·44 0 −1·44	
3569·8	+1·14 0 −1·14	
3460·2	.....	The separation was very narrow, and it may be an ordinary reversal.
2638·1	+1·34 0 −1·34	

General results of chromium and manganese.

The more important results of the preceding observations of the lines of chromium are:—

(1) The division of 2866·80 into eight constituents and a simple numerical relationship between them. The line 3147·23 divided into six and the line 2861·0 into five; the constituents of each of which are also numerically related in a simple way.

(2) Several lines which may be grouped together in having a similar appearance and polarisation and identical values of $d\lambda/\lambda^2$ for their constituents. Examples are the lines 2855·7 and 2757·75 which are divided into six, and the lines 3422·92 and 3358·64 which are divided into four. Also there are several lines amongst those divided into four whose values for $d\lambda/\lambda^2$ of their constituents are again simply numerically related.

(3) Amongst the lines which are divided into three, there are some which can be compared with each other in a similar way. And also the values of $d\lambda/\lambda^2$ for the constituents of some lines are simple multiples of the values of those of other lines.

(4) The various lines show various types in the appearance of their constituents. As regards the triplets the general appearance is that the middle constituent is at least twice as strong as either of the two outside ones; but there are some exceptions The middle constituents of several of the triplets are only a shade

stronger than the two outside ones, and several seem to be of equal intensities; in others the two outside ones are sharper and stronger than the middle one; and in others the three constituents are very diffuse. The differences are described in the preceding notes.

(5) The strongest lines are not those which are most widely separated; as a rule, the weaker ones have much higher values of $d\lambda$ than the stronger ones. This applies generally to all the elements so far examined.

(5) With regard to manganese, there are several lines amongst the triplets which may be compared and correlated, in that the constituents have the same values of $d\lambda/\lambda^2$ and similar appearance and polarisation. There are several lines divided into four, and the constituents of the quadruplet from 3473·9 are simple multiples of one another.

Generally, one of the outstanding facts of these investigations, and of those described in the previous papers, is that there are lines which divide into various constituents whose appearance is essentially the same, not only in their intensities, or diffuseness or sharpness, but also in the polarisation and the corresponding values of $d\lambda/\lambda^2$. It is an obvious speculation to suggest that, on the theory of the corpuscular structure of the atom, they represent the vibrations of similar groups of corpuscles.

The results of other elements will be published later.

I have to thank Professor Liveing for the use of his spectroscope, and Professor Larmor for his helpful interest in the work.

On the Specific Heat of Gases at constant volume and high pressure. By W. A. Douglas Rudge, M.A., St John's College.

[*Read* 12 November 1906.]

Few determinations have been made of the specific heat of gases at constant volume, and when such have been made the amount of gas used has been small. Joly, using his steam calorimeter, employed copper spheres 6·7 cm. in diameter, holding 4—5 grams of the gas. The author has been engaged for some time experimenting on the subject, and has obtained results which differ somewhat from those previously obtained. The carbonic acid used was that sold commercially in the small bulbs, or "sparklets," used for aerating water. A considerable mass of gas can thus be obtained in a small space. The gas is present in the liquid state, but on heating to 32° the liquid becomes converted into a gas, which is now at the very high pressure of 400 to 500 atmospheres. Attempts were made at first to determine the specific heat in the steam calorimeter after Joly's plan, but as the bulbs sometimes burst the method was abandoned.

Another plan was then adopted, which, after some modifications, took the following form:—A small calorimeter of copper, having a light framework arranged in it to hold the bulbs, was made. The frame was attached to a spindle which passed through the calorimeter cover, and was capable of being rotated by a small electromotor. As the experiments were made at fairly high temperatures, it was necessary to keep the calorimeter closely covered in order to prevent loss of water by evaporation. In making the experiments the bulbs were placed in position in the calorimeter and sufficient water added to cover them. The calorimeter was then heated to a temperature a few degrees higher than that at which the experiment was to begin. The whole apparatus was weighed and then placed in a felt-lined case, and the bulbs set in rotation. The temperature was taken by a thermometer passing through the lid of the calorimeter, and when it had fallen to a certain point, cold water was run in from a burette, and, after a few minutes rotation, the temperature of the mixture was noted. The calorimeter and its contents were quickly weighed and the weight of water added thus found. From the rise in temperature of the added water, the amount of heat lost by the calorimeter and the gas could be found, and, the heat capacity of everything but the gas being known, that of the latter could thus be easily calculated.

In the final experiments by this method, twelve bulbs containing about 50 grams of the gas were used. The pressure of the gas was calculated from the following data:—The average weight of gas in a bulb was 4·5 grams, and the internal volume was 6·25 c.c. At 40° the amount of gas at atmospheric pressure would occupy a volume of about 2620 c.c., the internal pressure being consequently $\frac{2620}{6{\cdot}25} = 420$ atmospheres, approximately. Amagat has shown that at 400 atmospheres pv for CO_2 is about the same value as at 1 atmosphere, *i.e.* Boyle's law holds good.

Between two and three hundred determinations were taken by this method, giving values for the specific heat of the gas, which varied from ·4 to ·68, the mean value being ·59. It was felt, however, that there were several small sources of error such as radiation losses, which were difficult to allow for, although it seemed that these should not exceed 10 per cent.

Then another method of working was tried. The contents of the calorimeter were heated by a current passing through a coil of Eureka wire immersed in the liquid. A calorimeter was constructed of thin copper, having a flat spiral of Eureka wire placed at the bottom. The bulbs were contained in a wire gauze cage, suspended upon a steel axis fixed to the calorimeter, which had a closely fitting lid, through which the rod attached to the cage, passed for the purpose of setting it in rotation.

If a constant electric current were sent through the coil, it would heat the contents of the calorimeter, and as long as the heat capacity of the whole remained constant, it might be inferred that in different experiments lasting for equal periods of time, and acting through the same range of temperature, the same amounts of heat would be involved. If, however, the heat capacity of the calorimeter and its contents varied, then the rise in temperature would be inversely proportional to the capacity.

The measurements were made as follows:—

(1) After weighing the bulbs and placing them in position in the calorimeter, the latter was filled with sufficient paraffin to cover the bulbs. The calorimeter was placed in a thickly-wadded case, and the bulbs set in rotation. A current was then sent through the wire and observations of the temperature taken at definite intervals of time.

(2) The gas was then removed from the bulbs by piercing a small hole which was afterwards soldered up. The empty bulbs were weighed in order to find the weight of gas formerly present. The bulbs were then returned to the calorimeter, care being taken to have exactly the same amount of paraffin as before. The current was sent through the coil and the observation of tempera-

ture and time taken as in (1). As the heat capacity was reduced, owing to the removal of the gas, the rate of rise of temperature was greater.

(3) The bulbs were next filled with water equal in weight to the gas originally present. This was effected by melting the solder and boiling the bulbs in water. On cooling, water entered, and its amount was adjusted so that the bulbs and water weighed the same as the bulbs did originally when filled with gas. The rise in temperature again was observed on the passage of the current, the rate again differing from that recorded in (1). As the heat capacity was now greater, the rate of rise in temperature was less. The experiment usually started at a temperature of 20° to 25° and was continued until it had risen to over 60°, but the actual rise made use of in the calculation was that from 36° to the temperature attained after an interval of ten minutes, 36° being chosen as a convenient point above the critical temperature, so that the actual measurement was made upon gas. As the current was kept constant during the three experiments, and the period of flowing was the same, it may fairly be assumed that equal amounts of heat were absorbed by the calorimeter and the contents. As the final temperatures were not far removed from each other, the very small difference in the heat developed owing to alteration in the resistance of the wire, was considered too small to have any very definite effect.

We have now three heat capacities to consider :—

(1) The calorimeter, the metal composing the bulbs, the paraffin and the gas.

(2) The calorimeter, bulbs, and the paraffin.

(3) The calorimeter, the bulbs, the water, and the paraffin.

The heat capacities being inversely proportional to the elevation of the temperature, from experiments (2) and (3), (since that of the water was known), that of the paraffin and metal could be deduced. Using the results obtained, in experiment (1), the heat capacity of the gas could be calculated.

The following is the result of a typical determination :—

Weight of bulbs full of gas	= 206·6
Weight of empty bulbs	= 154·3
Weight of gas used	= 52·3
Weight of calorimeter + bulbs, gas and paraffin	= 617·2
Weight of calorimeter + empty bulbs	= 564·9
Weight of calorimeter + bulbs filled with water	= 617·2

The curves plotted from this observation were quite regular, and it is of interest to note that when the curve is plotted for the gas from 20° to 60°, no break of continuity occurs between

31—32, showing that the latent heat of the liquid at the critical temperature is zero.

Table showing results of heating experiments.

Apparatus + gas		Apparatus − gas		Apparatus + water	
Time	Temperature	Time	Temperature	Time	Temperature
0	36·5	0	36·5	0	36·5
2	39·5	2	39·9	2	39·15
4	42·34	4	42·8	4	41·45
6	44·9	6	46·15	6	44·2
8	46·6	8	49·1	8	46·53
10	50·3	10	52·0	10	48·75
12	52·9	12	54·55	12	51·2
14	54·25	14	57·1	14	53·15
16	57·4	16	59·2	16	55·2
Rise	20·9°		22·7°		18·7°
Rise for 10°	13·8		15·5		12·25

Let the rise in temperature

of apparatus + gas $= \theta_1$,
of apparatus − gas $= \theta_2$,
of apparatus + water $= \theta_3$.

The heat capacities are therefore in the ratio of

$$\frac{1}{\theta_1} : \frac{1}{\theta_2} : \frac{1}{\theta_3},$$

and if m = mass of gas or water and x = capacity of the apparatus, *i.e.* calorimeter, wire, thermometer, paraffin and bulbs, and S = specific heat, then

$$\frac{1}{\theta_1} : \frac{1}{\theta_2} : \frac{1}{\theta_3} = x + mS' : x : x + m.$$

$$\therefore S = \frac{\dfrac{\theta_3 m}{\theta_2 - \theta_3}(\theta_2 - \theta_1)}{\theta_1 m},$$

and inserting the numerical values from the table

$$S = \cdot 45 \text{ nearly.}$$

Other experiments gave values from ·412 to ·508, the particular example being chosen because it was about the mean value.

The usually accepted value for the specific heat at constant volume is about ·172. Joly has shown, however, that the specific heat does increase with the pressure, and he found that an increase in pressure from 7·2 atmospheres to 21·66 atmospheres caused an increase in the specific heat of from ·16841 to ·17386. This increase is not great, but, if it went on at the same rate, it would make the specific heat about ·4 at 500 atmospheres. The gas used in the bulbs was made from coke and was dried by being passed through towers containing calcium chloride. There might have been a small amount of water remaining. The makers certify it to be chemically pure.

The author proposes to continue the work, using such other gases as can be easily sealed in the bulbs.

Estimation of Copper. By W. H. Foster, B.A., St John's College. Communicated by Mr H. O. Jones.

[*Read* 26 November 1906.]

In the *Proc. Camb. Phil. Soc.* 1902, Vol. xii. Pt. ii. p. 97, Wood and Berry describe a method of estimating sugar, by reduction of copper carbonate (dissolved in a solution of potassium carbonate), dissolution of the cuprous oxide formed in ferric sulphate solution, and titration of the reduced iron salt by pot. permanganate.

Jones and Carpenter, *J. C. S.* 1903, Vol. lxxxviii. p. 1394, give an account of a method of estimating hydroxylamine which is similar in principle to that used by Wood and Berry for the estimation of sugar. The investigation described in the following paper was undertaken with a view to ascertaining how far either of the two methods above referred to might when reversed, be applied to the estimation of copper, more especially in the presence of other metals.

By making use of the fact that most metals form readily soluble double carbonates with K_2CO_3 (in presence of $KHCO_3$) it seemed that a method of estimating copper in mixtures might be devised, which would be of some practical value.

The method of procedure consists in adding to a definite volume of the copper solution to be estimated (which should be of a convenient strength), a sufficient quantity of a saturated solution of a mixture of potassium carbonate and bi-carbonate, in order to produce a solution of the copper potassium carbonate which would not decompose on boiling. To this solution, preferably when at the boiling point, such a quantity of the reducing agent is added as will ensure the complete reduction of the copper carbonate to cuprous oxide. The mixture is then heated to boiling for about 10 minutes, and filtered rapidly by means of the Gooch filter, nearly boiling air free water being used in the washing of the cuprous oxide. The precipitate is now quickly transferred to a bottle filled with carbon dioxide gas, by means of a pointed glass rod, and the portion still adhering to the crucible washed into the bottle with a solution of ferric sulphate containing sulphuric acid. On shaking the bottle which must be provided with a stopper ground to fit it, in order that the shaking may be done vigorously, the cuprous oxide dissolves, and the resulting solution is titrated with standard $KMnO_4$ solution.

It will be seen that the method just described is a modification of that given in Sutton's *Volumetric Analysis*, 7th Edition, p. 175, and known as Schwarz's method. It differs from it, however, in that the ferric salt used is the sulphate and not the chloride and consequently the reduced salt may be titrated with $KMnO_4$

solution, the atmosphere of CO_2 preventing oxidation of the ferrous salt formed. Moreover the double carbonate of copper and potassium is employed instead of the tartrate.

A solution of copper sulphate was estimated first, and then a sample of electrolytic copper was analysed. With both of these, when sugar was the reducing agent, satisfactory results were obtained. An attempt was next made to estimate the copper in a copper coin, and in various mixtures of metals containing copper, but in these the results obtained were not so satisfactory. The probable causes of the discrepancies will be discussed in connection with the series of experiments in which they were observed.

Estimation of copper in copper sulphate.

Grape Sugar as Reducing Agent.

I. The solution contained 12·8760 gms. of the re-crystallised salt in 500 c.c.

For the titration 20 c.c. of the copper solution was taken, and 15 c.c. of the solution of K_2CO_3, $KHCO_3$ sufficed to give a solution which was permanent on boiling.

The reduction was effected by grape sugar, a 10 % solution being used in this instance, and the quantity added was considerably in excess of that required for complete reduction of the copper.

Results :—

(1)	20·47 c.c. of $KMnO_4$ sol.	(5)	20·47 c.c. of $KMnO_4$ sol.
(2)	20·32 „ „	(6)	20·46 „ „
(3)	20·47 „ „	(7)	20·50 „ „
(4)	20·47 „ „		

$$1 \text{ c.c. } KMnO_4 \text{ sol.} = \frac{20}{20{\cdot}75} \times {\cdot}00316 \; KMnO_4.$$

A mean of 20·47 c.c. gave 99·62 % of the theoretical weight of copper present.

[The copper sulphate employed above was found afterwards to contain a trace of iron.]

The precipitate of Cu_2O was easy to filter and to wash free from the brown liquid which formed during the reduction.

II. The solution used contained 13·1595 gms. $CuSO_4$, $5H_2O$ in 500 c.c.

20 c.c. of the solution was taken and
20 c.c. $K_2CO_3KHCO_3$ sol. added, and
7 c.c. of grape sugar (10 gms. in 500 c.c.).

$$1 \text{ c.c. } KMnO_4 \text{ sol.} = \frac{20}{19{\cdot}90} \times {\cdot}00316 \text{ gm. } KMnO_4.$$

Results:—

(1)	20·92 c.c. $KMnO_4$ sol.	(4)	20·90 c.c. $KMnO_4$ sol.
(2)	20·92 „ „	(5)	20·90 „ „
(3)	21·00 „ „		

A mean of 20·91 c.c. gave 99·84 % of the Cu actually present.

Estimation of the copper in a sample of the Electrolytic Copper.

I. 3·18 gms. of copper was dissolved in nitric acid and the solution made up to 500 c.c.

The grape sugar solution used contained 2·7 gms. of the sugar in 500 c.c. and about 30 c.c. was required to ensure the complete reduction of the 20 c.c. of the copper solution.

Results:—

(1)	20·46 c.c. $KMnO_4$ sol.	(4)	20·45 c.c. $KMnO_4$ sol.
(2)	20·48 „ „	(5)	20·42 „ „
(3)	20·47 „ „	(6)	20·48 „ „

$$\left(1 \text{ c.c. } KMnO_4 \text{ sol.} = \frac{20}{19{\cdot}90} \times {\cdot}00316 \text{ gm.}\right).$$

A mean of 20·46 gives 99·4 % of the whole of the copper in the solution.

[The copper used in this series of experiments was found to contain about ·5 % of silver.]

II. 3·5 gms. Cu in 500 c.c. 20 c.c. of this solution was used for each titration.

Results:—

(1)	22·10 c.c. $KMnO_4$ sol.	A mean of 22·06 gave 100·07 % of Cu.	
(2)	22·00 „ „		
(3)	22·10 „ „		

The sugar solution used was somewhat concentrated and excess was added. It is difficult no doubt to wash away completely the brown liquid produced during the reduction, when this is thick, as is the case when strong solutions of sugar are used. This may possibly explain why the result in this series is a little higher than it ought to be.

Hydroxylamine as Reducing Agent:—

The solution used contained 6 gms. $CuSO_4$, $5H_2O$ in 500 c.c. 1 c.c. $KMnO_4$ solution contained ·00316 gm. $KMnO_4$.

I. The hydroxylamine was used in the form of hydrochloride. The following numbers were obtained for 20 c.c. of the solution.

(1)	18·40 c.c. $KMnO_4$ sol.	(5)	18·60 cc. $KMnO_4$ sol.
(2)	18·70 „ „	(6)	18·75 „ „
(3)	18·70 „ „	(7)	18·50 „ „
(4)	18·80 „ „	(8)	18·70 „ „

Theory requires 19·38 c.c.

These results are fairly consistent, but they are about 3 % below what is required for the amount of copper actually present. No doubt a small proportion of the Cu_2O is dissolved by the undecomposed hydroxylamine, or by the ammonia which may be set free during the boiling, and as this escapes into the filtrate, we have an explanation of the low results. This explanation is borne out by the fact that whenever the filtrate was examined in cases where the results were lower than they ought to be, copper was found in it.

II. A solution of copper in nitric acid (3·18 gms. of Cu in 500 c.c.) gave, with NH_2OH as reducer, the following numbers:—

(1)	19·00 c.c. $KMnO_4$ sol.	(5)	19·25 c.c. $KMnO_4$ sol.
(2)	19·10 „ „	(6)	19·25 „ „
(3)	19·25 „ „	(7)	19·10 „ „
(4)	19·25 „ „		

20 c.c. of the solution was used.

$$1 \text{ c.c. } KMnO_4 \text{ sol.} = \frac{20}{19{\cdot}9} \times {\cdot}00316 \; KMnO_4.$$

19·20 c.c. gives 96·54 % of Cu.

This is again about 3 % below the actual percentage. Copper was invariably found in the filtrate when tested for.

Application to solutions of copper containing other metals.

I. *Copper. Tin. Zinc. Grape Sugar as Reducing Agent.*

An attempt was now made to estimate the copper in a solution containing also tin and zinc. The solution was prepared to resemble closely that which would be obtained by dissolving a copper coin. It contained 5·481 gms. Cu in 500 c.c.

$$1 \text{ c.c. } KMnO_4 \text{ sol.} = \frac{20}{19{\cdot}90} \times {\cdot}00316 \text{ gm. } KMnO_4.$$

20 c.c. of the solution required amounts of $KMnO_4$ solution varying from 33·90 c.c. to 36·57 c.c. The amount theoretically required was 34·30 c.c. and the quantity of $KMnO_4$ used exceeded this in nearly 70 % of the titrations. It was clear

therefore from this that there was here some disturbing factor and it was in all probability the zinc. When sugar was employed as reducing agent the presence of zinc seemed always to affect the result in the direction indicated above. It is possible (and very probable) that the zinc forms with the oxidation products of the sugar, an insoluble compound which remains behind with the Cu_2O. This being decomposed by the sulphuric acid in the ferric sulphate solution, reduces some of the $KMnO_4$, thus causing the results to be higher than they ought to be.

II. *Copper Coin. NH_2OH as Reducing Agent.*

An estimation of the copper in a 1904 halfpenny was also made, hydroxylamine hydrochloride being used to reduce. The results were fairly consistent as the following numbers show.

20 c.c. of the solution required.

(1)	31·40 c.c. $KMnO_4$ sol.	(4)	31·35 c.c. $KMnO_4$ sol.
(2)	31·30 „ „	(5)	31·40 „ „
(3)	31·30 „ „	(6)	31·60 „ „

31·40 c.c. gives 91·20 % of Cu, and the amount usually present in coinage is 95·5 %. It will be seen that the results are here about 4 % below what is required by the amount of copper actually present.

III. *German Silver. Sugar as Reducing Agent.*

A mixture was prepared to resemble German silver. It contained 4·5586 gms. Cu, 1·5 gms. Zn, 1 gm. Ni, and a trace of Fe in 500 c.c.

Ten titrations gave numbers varying from 28·2 c.c. to 30·37 for 20 c.c. of solution. The amount required by the Cu actually present was 28·65 c.c.

Half the titrations gave values greater than this. We see here again probably the influence of the zinc, since grape sugar was used to reduce. It should also be pointed out that the double carbonate which Ni forms with K_2CO_3 is one of the least stable of these double salts and is readily precipitated on boiling even in the presence of considerable excess of K_2CO_3, $KHCO_3$ solution. The precipitate moreover is finely divided and pasty so that filtering even with the Gooch filter is a slow process, and the washing of the precipitate cannot under these circumstances be very satisfactory.

IV. *German silver wire. NH_2OH as Reducing Agent.*

8·8830 gms. of the wire were dissolved in HNO_3 and made up to 500 c.c. The copper was reduced by means of hydroxylamine.

Results :—

20 c.c. of the solution required

(1)	34·20 c.c. $KMnO_4$ sol.	(4)	34·40 c.c. $KMnO_4$ sol.
(2)	34·70 „ „	(5)	34·30 „ „
(3)	34·40 „ „		

1 c.c. $KMnO_4$ sol. contained $\frac{20}{19{\cdot}91} \times {\cdot}00316$ gm. $KMnO_4$.

34·40 c.c. gave 61·80 % Cu.

By gravimetric methods 62·6 % Cu (mean).

The filtering of the precipitate was rather troublesome and the time taken for each determination was five or six times that required for an estimation in the case of a solution containing only copper when grape sugar was employed as reducing agent. Under favourable circumstances it would be possible to carry out about ten determinations of such a solution in the hour but not more than three or four of the solution of German silver.

V. *Brass. Grape Sugar as Reducing Agent.*

4 gms. copper were dissolved in HNO_3, sufficient zinc being added to make a mixture resembling brass, the whole being made up to 500 c.c.

1 c.c. $KMnO_4$ sol. = ·00316 gm. $KMnO_4$.

20 c.c. of the solution required amounts of $KMnO_4$ sol. varying from 25·00 c.c. to 26·10. Out of eight titrations six gave numbers above the theoretical value (25·20 c.c.).

Phenyl hydrazine as Reducing Agent.

Since $C_6H_5NH.NH_2$ when warmed with copper salts is known to give cuprous oxide, benzene and nitrogen, it appeared likely that it might prove to be a suitable reducing agent for the estimation of copper by this method.

A series of estimations of the mixture resembling brass were carried out with the object of ascertaining the behaviour of this substance as compared with grape sugar and NH_2OH.

The $C_6H_5NH.NH_2$ was used in the form of hydrochloride, which was prepared specially for the purpose and used in the fresh condition.

It was found necessary to wash the precipitated Cu_2O with alcohol, otherwise the solution in the ferric sulphate was turbid and the end point consequently not at all easy to determine. When washed with alcohol there was no difficulty whatever with regard to end point determination, the solution being as clear as

in the estimations with grape sugar and a solution containing only copper. The results were as follows:—

(1)	24·95 c.c. $KMnO_4$ sol.	(6)	25·10 c.c. $KMnO_4$ sol.
(2)	24·92 „ „	(7)	24·90 „ „
(3)	25·10 „ „	(8)	25·10 „ „
(4)	25·20 „ „	(9)	25·10 „ „
(5)	24·80 „ „		

20 c.c. Cu sol., 25 c.c. K_2CO_3 sol., 20 c.c. phenyl hydrazine HCl; (5 gms. is 500 c.c.) being used in each titration.

As the actual amount present required 25·20 c.c. it will be seen that in all the numbers except one the results are lower than they ought to be, but the discrepancy is not great. Phenyl hydrazine appears to behave somewhat similarly to NH_2OH but not to the same extent. The washing with alcohol lengthens somewhat the time for each titration but this would not be a serious objection if the reducing agent had been quite satisfactory.

In another series the numbers obtained were:—

(1)	21·15 c.c. $KMnO_4$ sol.	(6)	21·60 c.c. $KMnO_4$ sol.
(2)	21·60 „ „	(7)	21·20 „ „
(3)	21·70 „ „	(8)	20·50 „ „
(4)	22·15 „ „	(9)	20·30 „ „
(5)	21·65 „ „	(10)	21·20 „ „

The copper actually present required 22·05 c.c. In this series all the numbers except one are below this.

VI. *Copper and Nickel.*

It was found almost impossible to filter the precipitate (even with the Gooch filter), in any reasonable time, and the method was regarded as impracticable with solutions containing nickel in any considerable quantity.

* * * * * * *

Though not fulfilling the expectations formed of it at first, it would appear that the method described would be applicable to solutions containing copper alone, or with alkali metals only in addition. Grape sugar appears to be the only reducing agent admissible, for with hydroxylamine and phenyl hydrazine the results are invariably low for the reason already given. It is better however not to have great excess of sugar as the rather thick brown liquid formed during the boiling may be difficult to remove completely from the Cu_2O precipitate.

It is obvious that complications may arise when other metals are present and grape sugar is used to reduce, and this is especially

the case with zinc, nickel and iron, but these complications are not, as we have seen, always due entirely to the same cause.

The investigation seems to show that the method of Schwarz* modified as described above is capable of giving very good results with solutions containing copper alone, but that it cannot be applied to mixtures of copper and those metals with which it is usually associated in alloys and ores.

The investigation described above was undertaken at the suggestion of Mr H. O. Jones, M.A., Clare College, to whom the author is indebted for much advice and assistance during the progress of it.

* Schwarz, in his paper on the estimation of copper (Annalen der Chemie und Pharmacie, Vol. 84, p. 84 (1852)) gives only one titration number for each analysis carried out by him. It is not possible therefore to say whether his numbers were consistent or not, or whether he used the mean of all the numbers obtained by him, or only the more favourable ones.

The procession of Cnethocampa pinivora, Treitschke. By H. H. Brindley, M.A., St John's College.

[*Received* 29 October, 1906.]

The life history of *Cnethocampa pinivora**, one of the Eupterotidae, was first described in detail by Réaumur†, who made observations on families sent to him in Paris from the pine woods of the Landes in the neighbourhood of Bordeaux. As the nests of larvae suffered from the long journey by coach he supplements his own observations by quoting those of his correspondents at Bordeaux who collected the nests and on his behalf studied the species in its habitat. In the last century this moth was described and figured in its several stages by Ratzeburg‡, and in recent years by Fabre§, who has added much to our knowledge of its natural history. Its larva, which is found from Northern Germany to the Landes of France and the Mediterranean region, is processional, and marches in single file, i.e.

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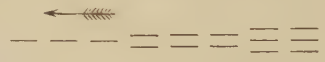
thus differing from that of *C. processionea* (Linn.), which infests oak trees, whose formation on the march is figured by Réaumur‖ as



and

(In both species the larvae on the march are always in close head to tail contact, which is not indicated in the above diagrams.)

Réaumur states however that the arrangement of the procession varies very greatly, even in the case of the same family from day to day: sometimes the larvae march in single file for a length of two feet, after which come several double files, then treble files, and so on with regularity till the larvae are eight or more

* *Thaumetopoea pinivora* in W. F. Kirby's *Catalogue of Lepidoptera Heterocera*, I. 1892, p. 592.

† *Mémoires pour l'histoire des Insectes*, II. Paris, 1736, pp. 149—161.

‡ *Forst-Insecten*, II. Berlin, 1840, p. 128 & taf. 8; also *Stettiner Entomologische Zeitung*, 1840, p. 40.

§ *Souvenirs Entomologiques*, sér. VI. Paris, pp. 298–392. (As usual, Fabre does not give the scientific name of the form he writes on, but his references to Réaumur's work and the account of his own observations leave no reasonable doubt that his "processionnaire du pin" is *C. pinivora*.)

‖ *loc. cit.* pp. 182—185 & pl. 11.

abreast. In some cases he saw as many as twenty abreast, but in all the procession was headed by at least one single file and so was invariably triangular in its general arrangement. Kirby and Spence* follow this account and A. H. Nicolai† has written a short work on the procession of this species. Ratzeburg‡ in the main follows Nicolai, stating that he himself has never seen a procession. There is need for further enquiry on the remarkable form of the procession of this species and as to the causes which produce the different arrangements of the larvae§.

Fabre's observations on *C. pinivora* were made on families kept in glass-houses floored with sand containing small pines at his laboratory near Avignon. He states that the imagos appear in July or August and deposit the eggs in cylindrical masses round the pine needles. Hatching occurs in September and the larvae soon commence to construct the silk nest which is so characteristic a feature of the pine woods in winter and spring.

The Procession.

The activities of the larvae on the nest tree are nocturnal, both the strengthening of the nest and the excursions therefrom being performed at night. The feeding expeditions are processional, the primite spinning a thread by the silk glands which is added to by the satellites in succession. On arrival at the food-branch the larvae separate, each continuing to lay down its thread. In winter and in early spring on fine mild days there are also occasional processions away from the nest tree over the neighbouring sand. The meaning of these expeditions is obscure, though Fabre hazards the fanciful suggestion that they represent "une promenade hygiénique, un pèlerinage de reconnaissance aux environs, peut-être un examen des lieux où se fera plus tard ensevelissement dans le sable pour la métamorphose." As originally recorded by Réaumur and confirmed by Fabre, the procession leaves the nest tree for the last time in the later weeks of March or early in April, in order to burrow for pupation. Fabre's chief conclusions regarding the procession are that (1) guidance by a secreted thread has arisen as a means of return to the nest because the activities of the species are nocturnal, and so is presumably more efficient than visual guidance; (2) the sense of smell is poor and is not employed for guidance; (3) there is never voluntary reversal by a larva on the thread, and artificial reversal results in entire loss of a sense of direction; hence a

* *Introduction to Entomology*, ed. 5, II. 1828, p. 23.

† *Die Wander- oder-Prozessionsraupe in naturhistorischer, etc., Hinsicht.* Berlin, 33. 40 pages. Unfortunately this work is not in Cambridge.

‡ *loc. cit.* pp. 119—126.

§ For further references to literature see W. F. Kirby, *loc. cit.* p. 591.

procession returning loops about till it finds the outward bound thread; (4) there is no special primite, and if a primite be removed artificially the next larva becomes leader with little hesitation; (5) removal of a satellite and the thread under it results as a rule in the formation of two chains, each going its own way, while less frequently a single chain is formed by the two daughter chains joining up; (6) there is no satisfactory clue to the influences which determine the course of the larvae, except that in some cases sunlight seems to attract the processions, and Fabre thinks it possible that warmth is really the stimulus.

Cnethocampa pinivora is common in the *Pinus Pinaster* woods of the Landes, and on April 2, 1906, my wife and myself found a procession in the Cap Ferret woods, which separate the Gulf of Arcachon from the Atlantic. In the more open spaces between the masses of pines there are much sea holly and common yellow broom. The day was warm, with constant sunshine, and the procession proved to be the final one, i.e., for pupation. The number of larvae composing it was 114, and thus it was not a very long one, for Fabre states that he has seen a procession as long as 12 m., containing about 300 larvae; and Mr Cleveland Morgan, Trinity College, informs me that in March, 1905 he found on the hills of the Algerian Tel processions of about 180 larvae, the species in question being either *C. pinivora* or some closely allied form. (The nomenclature of the Eupterotidae is in a very confused state, and it appears that much uncertainty exists as regards their distribution and specific characters.) The procession observed at Cap Ferret was moving without pause over the undulations and low vegetation of the sand, the primite rotating his head from side to side with a suggestion of "casting about." It seemed clear, however, that the general direction taken was after the greatest sunlight, and this held also in the main for the daughter processions formed by interference later on. That warmth, as Fabre has suggested, may be a guiding influence, and that in the more open and so more sunlit spaces there are wider expanses of sand free from vegetation and therefore perhaps more suitable for burrowing, are possibilities which suggest themselves in this connection. At the time of this observation I had not, to my subsequent regret, read Fabre's work, and so the few experiments made lacked its valuable guidance. The chief of these were:

(1) Placing every other larva of 30 contiguous ones on its own level about 15 cm. to one side of those left in position, thus

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this resulted in all the larvae "casting about" for a time though

on the whole continuing to move forward in the original direction, but now in two parallel broken chains. By degrees the larvae of each chain closed up and in 10 minutes there were two solid chains marching parallel.

(2) Breaking up a long chain by taking out several contiguous larvae here and there was tried twice, both times with the result that those left in place broke their formation and came to form a confused mass by circling round each other, the larvae removed soon mingling with the rest. Eventually from this mass an approach to a new chain was evolved, though when last seen there were still stragglers.

(3) Placing 4 larvae head to tail in as nearly a closed circle as possible resulted in their joining up and going round in a closed circle several times, a proceeding soon relinquished for a straight procession.

(4) Placing a single larva a little ahead of a short chain had the sequel of the leader of the chain catching up the isolated larva, which was accepted as primite with practically no hesitation.

In making these observations it was not possible to decide whether vision or the thread secreted by a predecessor was the more useful guide when "joining up" occurred. It was indeed often difficult or impossible to distinguish the fine thread on the glistening sand. The different results of making small breaks or large breaks in the normal procession, as in (1) and (2) above, are recorded for what they may be worth, for far too few observations were made to justify exact conclusions. Fabre observed that processions sometimes voluntarily broke up into circulating masses, and in such cases fatigue after long marching, darkness, and nocturnal cold seemed to him possible factors. At any rate the circulating mass is the normal formation in the nest and a procession belated away from home, as in some of Fabre's cases, might perhaps be expected to adopt the nest formation at nightfall. But by what process does the mass become a procession? It seems quite clear that any larva may act as a primite, and thus the doubt arises as to whether the primite does, in a strict sense, lead the procession. It seems not unreasonable to suppose that as all the larvae must be influenced at the same time by the same stimulus, hunger, sunlight, desire to pupate and so on, they all respond fairly equally, and thus it may be suggested that the whole chain proceeds as one individual, as seems to be the case in a chain of salps or of polychaetes freed from the budding individual, though the organic union between these is of course absent in *Cnethocampa*. But in one particular case the primite may perhaps take a real initiative, i.e., when burrowing is performed. We observed this process in the case of one of the daughter chains formed in (1) above. The spot

chosen was a slight depression in sand free from vegetation. The primite stopped against its steeper side and immediately attacked the sand with its mandibles, the satellites breaking away from each other and surrounding the primite with every appearance of watching its movements: certainly it was several minutes before any of them commenced to follow the primite's example. Soon all who could get near the latter began digging also, the primite quite disappeared in 15 minutes and when we left the spot some of the satellites had partially covered themselves. It is of course very possible, however, that the hesitation of the satellites was due to some special cause. Fabre observed that a procession of 100 larvae on the final march voluntarily broke up into short chains which burrowed in different spots, and that the cocoons were completed in 15 days.

In reference to the "closed circle" experiment (3) above, I find that Fabre gives a striking instance of this formation. He succeeded in arranging such a procession on the rim of a palm tub sunk in the sand, the larvae circling for seven days before they returned to the nest. The circle broke up into either one or two masses at nightfall, but reformed at daybreak. From the fourth day onwards small exploring parties set out, but till the seventh day returned to the circulating majority. The thread on which the larvae marched finally became 2 mm. wide by constant additions.

The few observations which the available time and other circumstances allowed us to make on a "wild" procession do little more than confirm the delightful account given by Fabre, and they are offered chiefly with the view of suggesting that there are several points of importance which should well repay fuller investigation than we could make: among which may be mentioned the extent to which the primite is a real leader of his chain of satellites, how far sight assists such events as "joining up" and the formation of a chain from a circulating mass, and to what extent a solitary larva secretes a thread. Again, Fabre states that in returning to the nest there is "casting about" ("des tâtonnements, des vagabondages") till the outward bound thread is encountered and followed up homewards, but it would be interesting to know what happens if this thread is struck again in the *outward* direction. The effects of temperature and light on the activities of the larva are not understood clearly. Fabre is inclined to think that the dorsal papillae are "appareils de météorologie" and Lapaury* has added a little to our knowledge of the effect of temperature on the procession. And though we have a suggestion as to the value of the processional habit in nocturnal feeding excursions on the

* *Ann. Soc. Ent. de France*, xvi. 1876, p. 244.

nest tree, it still remains to be shewn what advantages accrue from this formation when the larvae leave the tree to burrow. The very remarkable tendency to leave the tree and return to it without burrowing is perhaps the most obscure proceeding of this species.

Oviposition by Tachinids.

The Cap Ferret procession was the subject of continuous attack by Tachinid flies, apparently all of the same species. Unfortunately we did not secure a specimen, but with the kind assistance of Dr David Sharp and Dr F. J. H. Jenkinson we have since ascertained that it was almost certainly *Dexodes machairopsis*, which Brauer and Bergenstamm * state is the Tachinid particularly infesting *C. pinivora*. The usual event was that a fly, after hovering over the procession, dropped suddenly on the sand and used its wings, slightly opened, as vertical props to support its body, whose ventral aspect faced the procession. With the tips of its wings thus resting in the sand, the fly employed most or all of its legs for pushing against the larvae as they passed, while it repeatedly extended its abdomen ventrally and forwards in an endeavour to inject its eggs. Apparently the usual attempt was to insert the ovipositor on the naked ventral surface of the larvae, while the pushing with the legs served to keep the fly's head and thorax away from the lateral tufts of protective hairs. The unsteadiness of the fly in this curious position, the rapidity with which it made darts at the larvae, and the irregular stumbling of the latter under this hostile interference made exact observation difficult, but it seemed clear that in this sitting attitude a single fly often injected or endeavoured to inject several larvae in succession. It was, however, clear that there were very numerous failures to insert eggs in their intended host, as the ovipositor was as often as not thrust into the sand instead. Whenever the attack succeeded the larvae started violently, the wound was evidently felt acutely. The length of the procession made it impossible to guess what proportion of the larvae received eggs, but bearing in mind how numerous were the Tachinids, the vigour of their attacks and the time the larvae were exposed thereto, the impression gained was decidedly that very few could have escaped the oviposition. In one case we noticed a different procedure by a Tachinid: it alighted on the head of a larva, ran rapidly, apparently with much discomfort, along its back, and then inserted its ovipositor close to the hind end. The longer hairs are grouped in tufts on either side of the mid-dorsal line and project outwards, so it seemed as though the

* *Denk. Akad. Wien.* LXI. 1905, p. 551.

fly was endeavouring to avoid their points by keeping in the middle of the back. This was the only instance of the kind noticed. It was clear that the hairs of the larvae were sedulously avoided. Their defensive power against Tachinid attack has been emphasised by Weeks* in his description of oviposition in larvae of *Datana*. Fabre omits reference to oviposition in *C. pinivora* (possibly his families being kept under glass were preserved from this attack), but devotes a chapter† to the urticating properties of the hairs and states that their toxic power is greatest after the final ecdysis, which is apparently the second, as he merely mentions that the larva "a trois costumes." He figures, as does also Ratzeburg, the hairs as armed with numerous short teeth and states that the urticating secretion passes along the hairs from cutaneous glands. He also describes how his face and eyelids were much inflamed after a morning's handling of the final instar of the larvae, and that very great irritation is produced by rubbing the skin with a concentrated ethereal extract of the larval epidermis. Réaumur‡ describes similar experiences in the case of *C. processionea*, and that he also suffered from handling larvae of *C. pinivora*. Mr H. Scott, Trinity College, informs me that in Algeria he has heard of much irritation of the skin in the case of an Arab who had been occupied in clearing a piece of ground of companies of *C. pinivora* or some closely allied form. In the case of the Cap Ferret procession, the larvae being on their way to burrow, the toxic power of the hairs would, according to Fabre, be at its greatest, and it was quite obvious that they were dreaded by the Tachinids, but neither of the observers noticed any irritation after handling the larvae and bringing the eyes very near them. Very possibly, however, the toxic effect on the human skin is often not great in the open air, and would be noticeable only after longer contact with the larvae than in the present instance. Réaumur and Fabre give very interesting accounts of the "simples" they employed for relief from the irritation, the former finding parsley and the latter purslane the most effective remedy.

The pine woods of Cap Ferret are easily reached by steamer from Arcachon several times a day and anyone who would devote a few days in the last two weeks of March to observations on the "processionnaire du pin" could do much towards filling the many gaps in our knowledge of it. I am indebted to Dr David Sharp for much kind advice in compiling these notes, especially as regards nomenclature and the literature of the subject.

* "Method of oviposition of Tachina," *Entom. Amer.* III. 1888, p. 126.
† *loc. cit.* p. 378.
‡ *loc. cit.* p. 191.

Electrification produced by heating Salts. By J. J. Thomson, F.R.S., Trinity College, Cavendish Professor of Experimental Physics.

[*Read* 12 November, 1906.]

Beattie found that when sodium chloride mixed with iodine is sprinkled on a metal plate, large quantities of positive electricity and some negative electricity are given off when the plate is heated to a temperature somewhat over 300° C. This and similar effects have been investigated by Garrett and Willows, who find that the electrification is due to the formation and subsequent dissociation of the iodide of the metal of which the plate is composed. Wehnelt has shown that when an oxide of calcium or barium is heated large quantities of negative electricity are given off. The following experiments were made with the object of seeing whether any light could be thrown on the phenomenon by investigating whether there was any relation between the sign and amount of the electricity given off when the salt is heated and the chemical nature of the salt.

Method.

The salt to be investigated was placed on a porcelain tube, this tube was filled with a badly conducting powder called 'Kryptol,' and the heating was effected by passing a current of electricity through the powder. This method was found to be very convenient, as by altering the current wide variations could be produced in the temperature, and, what is more important for these investigations, the temperature can be kept very uniform. As the porcelain when heated was found to give off considerable quantities of electricity, the part surrounding the kryptol was

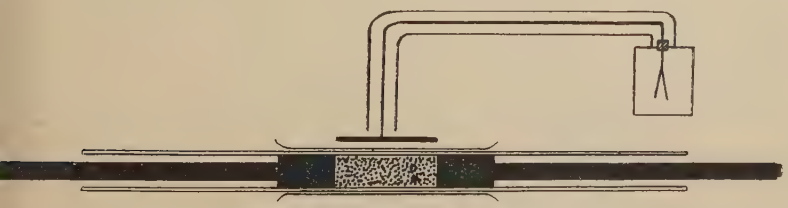

Fig. 1.

wrapped with thin mica which gives off very little electricity, and the salt to be tested was spread thinly and uniformly over the

mica. The electrification given off by the salt was determined by means of a saddle-shaped conductor suspended over the salt, and carried by an insulated rod connected with the gold leaves of an electroscope, the rod was surrounded by an earth connected metal tube to screen it from induction. The electroscope was charged positively or negatively, and the rate of leak determined in each case. If the salt gave off positive electricity the electroscope would leak faster when charged negatively than when charged positively, while the leak for a positive charge would be greater than for a negative one if the salt gave out negative electricity. Even when the tube was at a red heat, the temperature most frequently employed, there was little leak of the electroscope with either charge if no salt were placed under the conductor. A large number of salts were tried, and it was found that the sign of the electrification given off by these when heated depends not on the metal but on the class of the salt. The results are summarized below.

Phosphates.

All the phosphates I have tried, viz. those of Al, Fe, Hg, Ca, Zn, Pb, Ag, Sn, give off positive electricity when heated, some of them, such as aluminium phosphate, iron phosphate, mercuric phosphate in very large quantities, while the phosphates of Pb, Ag, Sn, at a red heat give off much smaller quantities. Aluminium phosphate at this temperature gives off more positive electricity than any salt I have tried, the emission is so great that it can easily be measured with a galvanometer. The amount of electricity given off was much the same whether the salt was in air at atmospheric pressure, in air at the pressure of a few millimetres of mercury, in hydrogen or in carbonic acid gas. The rate of emission falls off with continuous heating, and after an hour or more, the time depends on the temperature, is only a fraction of its initial value. There is no visible chemical decomposition. A current of air was passed over the glowing salt for several hours, bubbling through water just after leaving the salt, at the end of the time however the water showed no signs of any acid reaction. This copious admission of positive electricity by aluminium phosphate facilitates the passing of the arc discharge when the anode is a hot wire coated with the phosphate, the arc going with distinctly greater ease when the anode is hot than when it is cold. The amount of positive electricity given off by these hot phosphates is of quite a different order from that given off by clean metal at the same temperature; this explains why Professor Richardson, in his experiments on the emission of positive electricity from glowing wires, found that a speck of phosphorus which had acci-

dentally got on the wire enormously increased the discharge of positive electricity.

Nitrates.

The nitrates when heated get rapidly converted into oxides, but in the early stages they give off positive electricity.

Chlorides.

Give a small excess of positive but nothing like so much as the phosphates.

Oxides.

These when heated give out an excess of negative electricity, the most copious streams coming from the oxides of calcium and barium.

Connection between electrification by heating and electrification by friction.

If a salt when heated gives off an excess of positive electricity the salt itself will be negatively electrified, while if it gives off an excess of negative the salt will be positively electrified. I have found that the sign of the electrification produced by heating is the same as that produced by friction of the dry salt when cold and finely powdered. To test the electrification produced by friction the salt was placed in a mortar and rubbed with a dry pestle, the salt was then poured into an insulated cylinder connected with an electroscope, and the sign of the electrification given to the gold leaves tested, the substances on which the salt was placed while being rubbed and the substance with which it was rubbed were changed without making any difference in the sign of the electrification of the salt.

The results are shown in the following table:

Phosphates.

	Electrification by heating.	Electrification by friction.
Al	–	
Ca	–	–
Zn		–
Pb	– (slight)	–
Sn	– (slight)	–
Mg		–
Fe	–	
Hg	–	
Ag	– (slight)	

Oxides.

Ca	+	+
Al		+
Pb PbO	+	+
Pb Pb_3O_4	+	+
Pb PbO_2	+	−
BaO	+	+
BaO_2		+
Fe_3O_4		+
Fe_2O_3		−
Bi_2O_3	+	+
SnO	+	+
SnO_2		−

Nitrates. These give but little electrification when rubbed, but the electrification is always negative, the same as that produced by heating the salt.

Chlorides and iodides give slight negative electrification when rubbed, the yellow as well as the red form of HgI_2 was tried, both forms become negatively electrified. The carbonates and sulphates give very little electrification when rubbed and the sign of it is very capricious.

It will be seen that with the exceptions of the highest oxides of a metal electrification by heating gives the same sign as that by friction. In the case of the highest oxide the discrepancy is due to the fact that this oxide would at the high temperatures used be converted into a lower oxide.

From the agreement between the electrical effects produced by rubbing and heating we may conclude that the process by which the salt gets electrified is the same in the two cases. This suggests that the salts are covered with a double layer of electrification; in the case of the phosphates the positive layer is outside, the negative inside, while in the oxides the negative is outside, the positive inside, and that electrification is produced by the partial removal of the outer layer, by rubbing when the electrification is produced by friction and by the heat when the electrification is produced by heating the salt.

There seems no reason why the presence of the double layer at the surface of a body should be limited to the case of salts. If it is present in all bodies, then, as I suggested some years ago, electrification by friction may always be due to the removal of one or both of the outer coatings of the double layers covering the bodies which are rubbed together.

I wish to express my thanks to Mr E. Everett for assistance in the experiments with the hot salts, and to Mr W. H. Hayles for making the experiments with the cold ones.

On Secondary Röntgen Radiation. By J. J. Thomson, F.R.S., Trinity College, Cavendish Professor of Experimental Physics.

[*Read* 12 November, 1906.]

McClelland* has shown that there is a close connection between the secondary ionization given out by a substance exposed to the β and γ rays from radium, and the atomic weight of the body.

The experiments hitherto made on secondary Röntgen radiation have not indicated that any such connection exists between the secondary Röntgen radiation and the atomic weight. The following experiments show however that a very intimate relation does exist between these quantities and that this relation varies in a very interesting way with the hardness of the primary rays.

The method used in this investigation is illustrated in Fig. (1). A Röntgen ray bulb contained in a lead box gave off rays, a pencil of which passing through the aluminium window (A) bombarded a horizontal circular plate (B) of the substance placed directly below it. The plate was of diameter 5 cms. and was surrounded by a larger earthed plate of aluminium (D) which served the purpose of a guard-ring. This guard-ring plate was supported from one side by a turn-table having an up and down screw adjustment. Thus the guard-ring could be raised or lowered so that its upper surface was always in the plane of the upper surface of the inner disc.

Parallel to the metal plate and symmetrically situated above it was mounted an iron wire gauze plate (C) (2 mms. mesh), braced at the edges with a wire ring. The wire gauze was supported, like the guard-ring, from one side by a turn-table. By screwing the turn-table up or down the wire gauze plate was raised or lowered by an amount measured by a scale and vernier. The reading was taken when the wire gauze was touching the metal plate. Thus in any subsequent position of the wire gauze, its distance from the metal plate beneath it was known.

By rotating the turn-table the wire gauze could be swung clear of the apparatus. This was useful when one plate had to be substituted for another, for the wire gauze could afterwards be swung back exactly to its old position, the height being corrected for any difference in thickness of the metal plates.

The wire gauze was connected to a battery of small storage cells and raised to a sufficiently high potential—200 volts was used—to produce the saturation current across the region between the wire gauze and metal plate.

* *Scientific Trans. Roy. Soc. Dublin*, 1906.

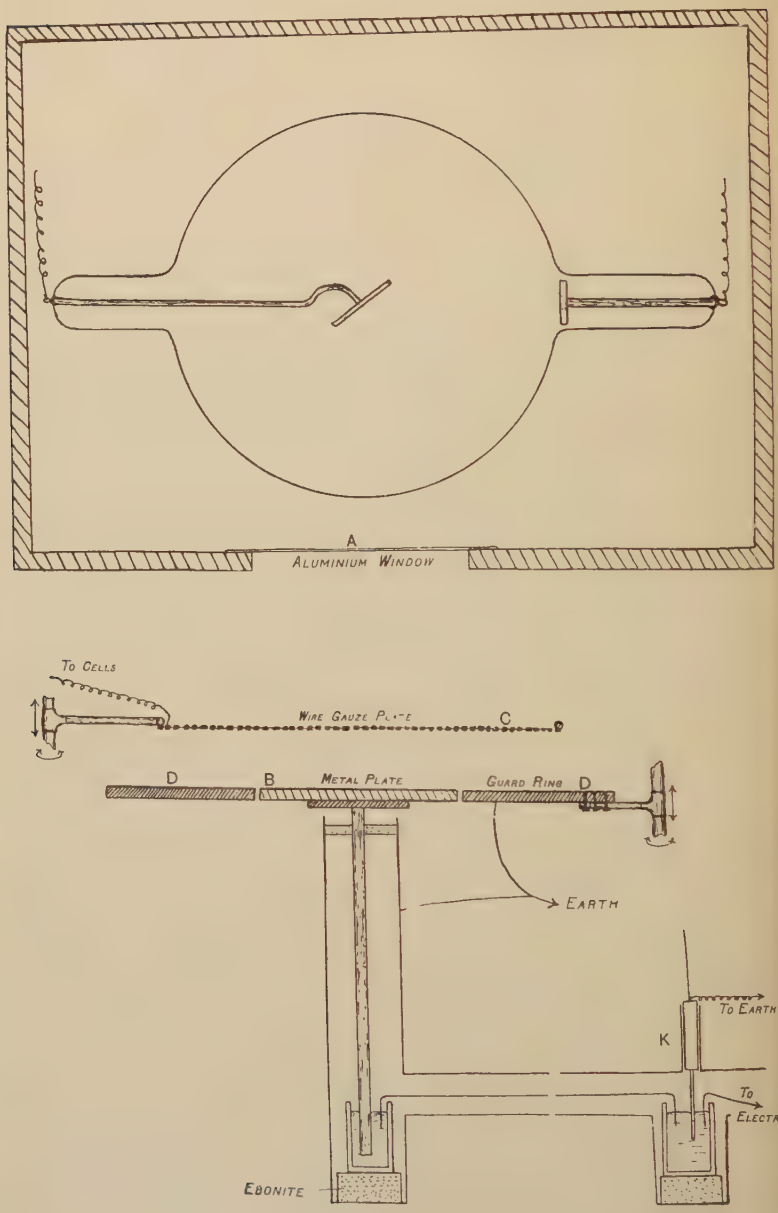
A
Aluminium Window
To Cells
Wire Gauze Plate
C
D
B
Metal Plate
Guard Ring
D
Earth
To Earth
K
To
Electroscope
Ebonite

Fig. 1.

The metal plate rested on a smaller plate of aluminium, connected as shown in Fig. (1) to a Wilson tilted electroscope which was well removed and well screened from the Röntgen rays.

Except in the case of the very soft primary rays it was not necessary to have the electroscope extremely sensitive. About 10 divisions of the eye piece scale per volt was the usual value.

The electroscope was connected through a mercury key (K) which could be operated from a distance, and by means of which the gold-leaf system could be earthed or insulated.

The connecting leads were shielded throughout by earthed metal tubes to avoid induction effects.

Whenever possible a metal was used with the surface polished. This was so in the case of lead, thallium, mercury, platinum, tin, cadmium, silver, zinc, copper, nickel, iron, calcium and aluminium. The remainder were used in the form of fine powder packed tightly into circular aluminium trays 5 cms. diameter, 7 mms. deep, and with very thin rims. The upper surface of the powder was flush with the rim. Bismuth, tungsten, tellurium, antimony, molybdenum, selenium, arsenic, cobalt, manganese, chromium, titanium, sulphur, phosphorus (red), magnesium, carbon and boron, were used in the form of powder.

For mercury, a similar iron tray was used.

We owe the pure selenium to the kindness of Mr Threlfall, F.R.S.

In some cases the same metal was used both as a plate and in the form of powder. The agreement in the results obtained was very close.

An observation lasted usually from half a minute to a minute, and the Röntgen bulb was given 2 minutes rest between successive observations. This, of all the methods tried, was found to be the most satisfactory for yielding results which were concordant.

The hammer-break of the induction coil also required repeated attention, the surfaces of contact being kept smooth and bright, parallel and plane.

In a comparison of the secondary radiation from two metals, readings were taken alternately a great many times, first with one metal and then with the other.

It was convenient to use different thicknesses for the different metals. The thickness varied from 7 mms. in the case of aluminium to about 1 mm. in the case of platinum and the densest metals.

In the case of some of the powdered non-metals it was found that they became electrified through friction in packing them in the tray. However, a few minutes bombardment with the rays sufficed to dissipate this charge.

For non-conductors such as sulphur the surface was made conducting by sprinkling over it a very thin deposit of graphite.

In some cases a sheet of gold-leaf was laid over the surface,

instead of using graphite. A correction had to be applied for the secondary radiation due to the gold-leaf alone.

The saturation current was measured in two cases.

1. When the plates were separated by 1 mm. of air, at atmospheric pressure. There is but little diminution in the intensity of the rays in passing through a layer of this thickness so that the ionization will be proportional to the product of the intensity of the rays and their absorption by the air.

2. When the plates were separated by 15 mms. of air at atmospheric pressure. The secondary rays are practically completely absorbed by this thickness of air so that the ionization in this case measures the energy in the stream of secondary radiation coming from the metal. As the absorption of the secondary radiation by the metal is much greater than that of the primary the stream of secondary radiation is equal to I/A where I is the energy in the secondary radiation emitted by a layer of unit thickness, and A the fraction of energy absorbed when the secondary radiation passes through this layer.

The connection between the secondary radiation and the atomic weight would probably be brought out more clearly by determinations of I, than by those of I/A. The advantage would however be neutralized to a considerable extent by the fact that the values of I/A can be determined with much greater accuracy than those of I.

An inspection of the curves will show that there is a very close connection between the values of I/A and the atomic weight. In every case except nickel an increase in atomic weight is accompanied by an increase in the stream of radiant energy. From the curves we should conclude that the atomic weight of nickel is greater than that of cobalt.

The slope of the curve is by no means uniform: at places it is very steep, indicating that a small increase in atomic weight is accompanied by a large increase in the secondary radiation.

It will be noticed that the places where the jumps occur depend on the hardness of the rays, and that with hard rays the jumps occur at higher atomic weights than with soft rays.

Thus with hard rays the first big jump occurs between titanium and chromium, while with soft rays it occurs between aluminium and calcium.

The steepest parts of the curves show a tendency to occur at the middle of the groups of the periodic series.

The unit of secondary radiation is quite arbitrary and is different in the different curves.

The measurements from which the curves were drawn were all made by Mr G. W. C. Kaye of Trinity College. I wish to thank him for the assistance he has given me.

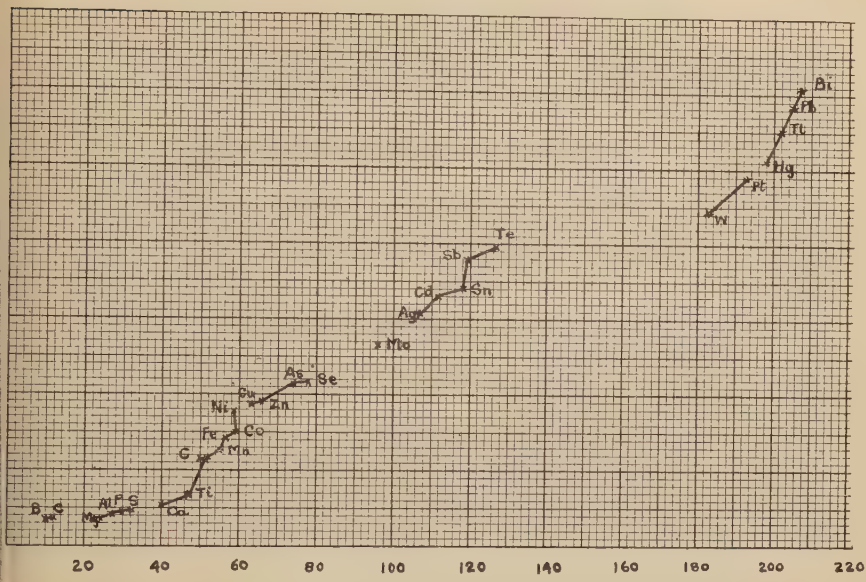

Fig. 2.—Hard Primary Rays. Plates 15 mms. apart.

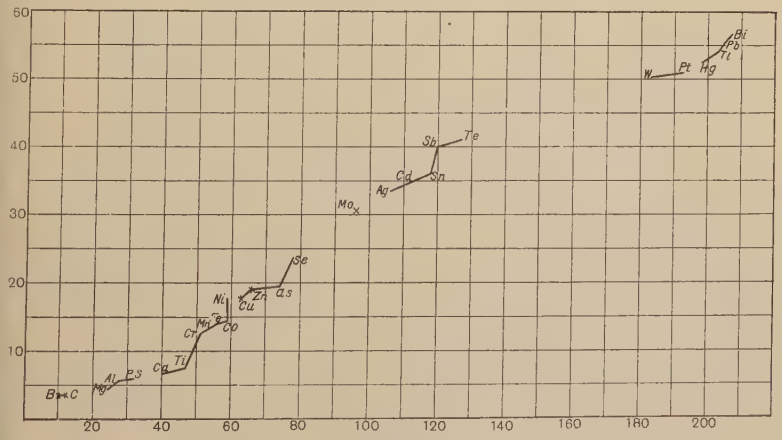

Fig. 3. Hard Primary Rays. Plates 1 mm. apart.

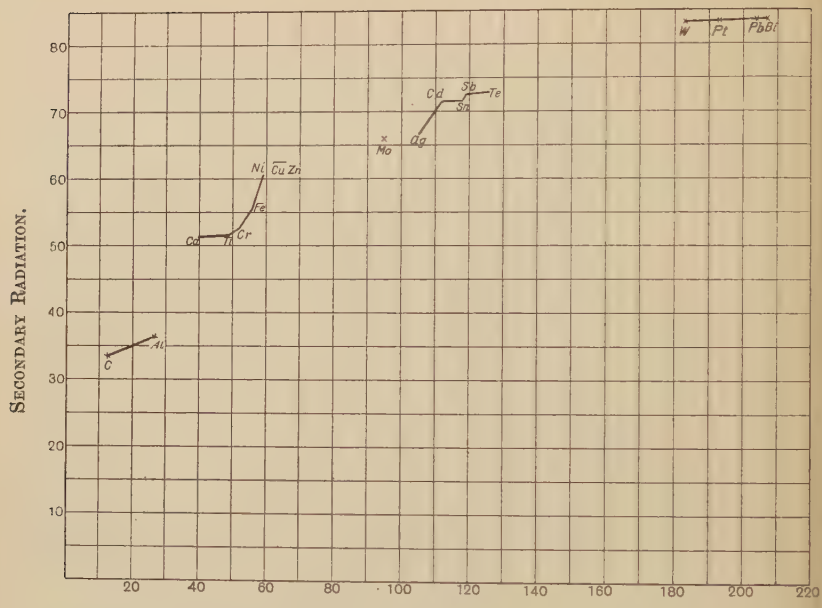

Fig. 4. Soft Primary Rays. Plates 15 mms. apart.

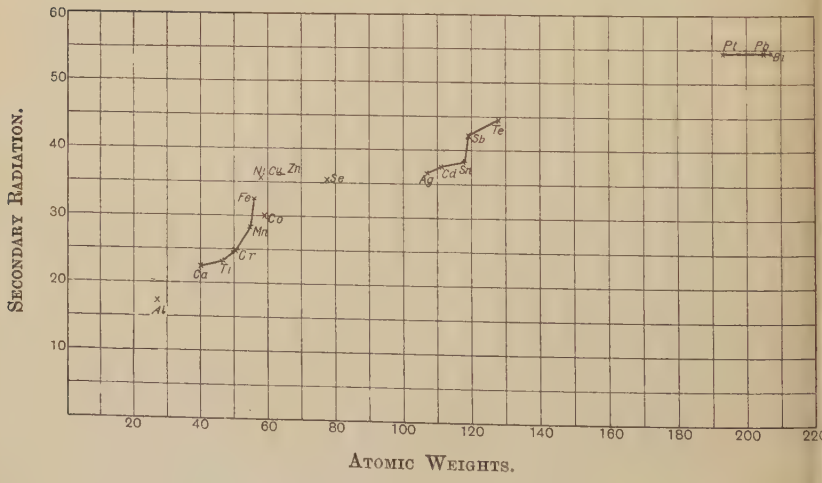

Fig. 5. Very soft Primary Rays. Plates 1 mm. apart.

A New Chemical Test for "Strength" in Wheat Flour. By T. B. Wood, M.A., Gonville and Caius College.

[*Received* 18 February, 1907.]

Flour made from different varieties of wheat, or from wheat of the same variety grown in different districts, produces, when baked, bread of varying character. For instance, some flours absorb, when made into dough of suitable consistency for baking, nearly three-quarters of their own weight of water, whilst others can take up less than one-half. Again the loaf baked from the same weight of two different flours may vary more than thirty per cent. in volume, the shape may be entirely different, and on cutting the two loaves across they may be found to vary enormously in both colour and texture.

The question of baking value or "strength" as it is commonly called, was recently fully discussed by Humphries and Biffen[1], who adopt as their definition of the strength of a flour "its capacity for making a large, well-piled loaf," a definition which excludes water-absorbing power, but which appears to include at any rate the three qualities of size, shape, and texture.

The definitions of strength adopted by authorities on baking vary widely, and no one appears to use the word to denote a single quality. This probably explains the very divergent results obtained by numerous investigators, who appear to have tried to find a single chemical or physical explanation for the sum of several quite independent properties.

The cause of strength has always been supposed to reside in the proteids of the flour. Various investigators have suggested from time to time that it was due (1) to the percentage of total proteid in the flour, (2) to the percentage of alcohol soluble proteid or gliadin in the gluten or total proteid, or in the flour. Undoubtedly, each of these factors is associated with strength in many cases, but there are so many exceptions that none of the suggestions can be said to solve the problem of the meaning of "strength."

When beginning to work at the subject, it seemed to me that it was useless to attempt to find a single explanation of so complex an idea. Probably each of the factors which make up "strength" is more or less independent of the others, and must therefore be attacked as a separate problem. Up to the present therefore I have directed my attention chiefly to investigating the conditions which influence the volume of the loaf produced by a given weight of flour.

[1] *Journal of Agric. Science*, Vol. II. No. 1, p. 1.

In baking bread, flour, water, and yeast are mixed together in certain proportions, the mixture being called dough. The dough is allowed to stand in a warm place while it undergoes the change known as "rising." This rising is caused by the yeast finding sugar in the flour, which it converts into alcohol and carbon dioxide gas, the latter of which being held in the dough increases its volume. It seemed therefore that the volume of the loaf should depend on the expansion of the dough by the carbon dioxide formed by the growth of the yeast, and this expansion must in turn depend either on the amount of sugar at the disposal of the yeast, which would decide the volume of gas formed, or, if there were abundance of sugar in all flours, on the capacity of the dough to retain a large amount of gas. The first of these suppositions was obviously the easier to test, and it has been found to give, in all cases tested, a satisfactory explanation of the cause of the size of the loaf.

To test this supposition that the volume of the loaf is due to the amount of sugar at the disposal of the yeast, a number of flours were obtained from Mr A. E. Humphries, Chairman of the Millers' Association, and of the Home-grown Wheat Committee, who has had much experience in measuring the practical baking value of flours, and who has helped me continually with material and advice throughout the investigation. Small weighed quantities of these flours were mixed with yeast and water in bottles connected with measuring tubes. The bottles were then incubated at a temperature of 35° C., and the volumes of carbon dioxide evolved from each recorded at intervals. It was at once noticed that all commenced to evolve gas at practically the same rate but that after about an hour some continued to do so at the original rate, whilst others gradually slowed down. After about 24 hours, when all had ceased to give off gas, the total volumes were read. In the following table the total volume of gas evolved by 20 grams of each flour treated in this way is recorded, side by side with the "strength" as determined by Mr Humphries in the bake-house. Mr Humphries defines strength "as the capacity for producing a large well-piled loaf," and it will be noticed from his definition therefore that volume is a large factor in his measurements. His scale is a purely arbitrary one in which the best flour he could obtain gets 100 marks, whilst the mark 0 represents a flour which is unbakeable.

Inspection of the table at once shows that the volume of gas given off closely follows the baker's marks, with two notable exceptions in nos. 1 and 8. These two exceptions after enquiry gave perhaps the strongest proof of the rule. It was found that no. 1 only obtained a mark of 96 when baked after mixing with malt extract, a treatment which would undoubtedly increase the

sugar at the disposal of the yeast by its diastatic action on the starch of the flour, and in this connexion it may be remarked that it appears to be a common practice with bakers to use malt extract to increase the size of the loaf. When no. 8 which had been marked as low as 20 was found to give off such a comparatively large volume of gas, enquiry was made and it was found that the baking tests with it had been made six weeks previously.

	Baker's Marks	c.cm. CO_2 given off by 20 gms. in 24 hours	% sugar required to give CO_2	% sugar found by analysis	% sugar from hydrolysis of starch
1. Manitoba	96	270	5·4	2·2	3·2
2. Fife	90	325	6·5	2·6	3·9
3. Indian	73	274	5·5	2·0	3·5
4. Australian	68	227	4·5	2·5	2·0
5. English	65	205	4·1	1·9	2·2
6. French	45	156	3·1	1·7	1·4
7. Rothamsted	36	131	2·6	1·6	1·0
8. French	20	287	5·7	1·8	3·9

Gas measured at room temperature and pressure, percentages of ugar calculated as glucose.

t at once occurred to me that it might be a case of rapid im-provement in quality on keeping which is sometimes noticed in ertain flours. I therefore asked that another test should if ossible be made. This was done, and the report came back that t now "marks 40, giving a large loaf but of bad shape." As olume only is in question, this report clearly puts this apparent xception in its proper place, and it appears therefore that in all he cases which have been tried, the volume of the loaf as deter-nined by baking experiments closely follows the volume of carbon ioxide evolved by incubating the flour with yeast and water. have baked no. 8 myself, and find that it produces a loaf inter-nediate in size between Fife and Indian.

From the volume of carbon dioxide evolved the approximate mount of sugar used up by the yeast can be calculated, and this given as percentage of each flour in the table. Side by side ith this column are the percentages of sugar in the flours, as etermined by extracting with cold water, removing the proteids, verting the sugar present in the solution, and estimating the uprous oxide produced by boiling with Fehling's solution. This etermination presents considerable difficulties: flour extracts are

hard to filter clear, and the proteids are troublesome to remove. On examining the figures, it is evident that the sugar contained in a flour is not nearly sufficient to account for all the carbon dioxide evolved when fermented with yeast. Flour however is well known to contain a diastatic enzyme, which no doubt accounts for the balance of sugar required by the yeast, the figures for which are given in the last column of the table. The diastatic power of each of the flours is at present being determined with a view to checking these figures.

In applying the above ideas to testing flours, there are clearly two ways of proceeding: (1) to make chemical determinations of the sugar contained in the flour as such, and of the sugar formed by incubating the mixture of the flour and water at such a temperature and for such time as is commonly used in baking (for instance, for three hours at 30° C.); (2) to mix the flour with yeast and water, and measure the carbon dioxide evolved during the fermentation.

Of these two methods the latter is very much easier to carry out and, it is suggested, gives very valuable indications of that particular component of strength which is concerned with the volume of the loaf. If this is so, the addition of sugar to flours which make small loaves, should produce an increase in size, and this has been found to be the case by actual baking experiments: for instance, in one experiment the addition of one per cent. of sugar to ordinary household flour as bought in Cambridge was found to make an increase of two per cent. in the weight, and thirteen per cent. in the volume of the loaf.

The author hopes shortly to make a communication dealing with the causes of the other components of strength.

Preliminary Note upon the Presence of Phosphorus in Crystalline Egg Albumin. By Miss E. G. Willcock, Newnham College, and W. B. Hardy, F.R.S., Gonville and Caius College.

[*Received* 20 February, 1907.]

Egg albumin is regarded ordinarily as a proteid which does not contain phosphorus in its molecule.

Both the crude amorphous precipitate, and the crystalline form obtained by Hopkins' method have frequently been analysed, but the presence of phosphorus has been mentioned in such analyses only by Osborne and Campbell[1]; in their analysis moreover, it figures as being present in the form of associated phosphate, rather than as an integral part of the proteid molecule.

Our investigations show

(1) that phosphorus is an inalienable constituent of crystalline egg albumin,

(2) that it is present as "organic" phosphorus.

Therefore, if the crystalline product be a chemical individual, as Hopkins[2] urges, it is a truly phosphated proteid.

The material used by us was prepared by Hopkins' method, that is, by the use of ammonium sulphate and acetic acid. Preparations were also used, in which sulphuric acid was substituted for the acetic acid. The rotatory power in each case accorded well with that given by Hopkins, viz. 30·7 and was constant throughout many crystallisations.

The nature of the Phosphorus.

1. The proteid was rendered insoluble, either by boiling or by long treatment with alcohol. The insoluble body was first extracted with many changes of water for eleven days, then with many changes of alcohol, ground up with ether to a fine powder, and finally extracted with three lots of 50 % acetic acid at 40°. The product was found to contain phosphorus, apparently in undiminished amount. Calcic phosphate, similarly treated, dissolved.

2. A specimen was washed with a slightly acid solution of sodium chloride until the washings were free from sulphate. It was then dried and washed for many days with specially pure distilled water until free from chloride. It was now dried and divided into two parts, one of which was ashed in presence of potassium nitrate and potassium carbonate, while the other was ashed with great care without the addition of salts. In the

[1] *Journ. Amer. Chem. Soc.* xxii. 422, 1900.

[2] *Journ. of Physiology*, xxv. 306, 1900.

second case, we found the ash to give no test for phosphorus, a result which agrees with Hopkins' analysis of the ash of carefully washed albumin. In the former case, in which we added bases, abundant phosphorus was present in the ash. This would seem to show that the phosphorus is "organic."

ESTIMATIONS.

I. Neumann's Method. Proteid prepared by acetic acid method.

2nd crystallisation	0·128 % P
4th „	0·127
6th „	0·126.

II. Neumann's Method. Proteid prepared by acetic acid method.

2nd crystallisation	0·126 %.

III. Neumann's Method. Proteid prepared by sulphuric acid method.

2nd crystallisation	0·131 %.

IV. Pemberton's Method. Proteid prepared by acetic acid method.

2nd crystallisation	0·140 %.

V. Woy's Method. Proteid prepared by sulphuric acid method.

2nd crystallisation	0·140 %.

The mean value therefore is 0·13 %. This agrees fairly well with Osborne and Campbell's value of 0·124 %. This constancy throughout so many fractions furnishes good reason for regarding the phosphorus as being a part of the molecule.

Hopkins found 1·57 % of sulphur present. If the phosphorus be taken at our figure 0·13 % it points to there being in the molecule 12 S to 1 P and the molecular weight of the proteid works out at 23800.

PROCEEDINGS

OF THE

Cambridge Philosophical Society.

Notes on the Proportion of the Sexes in Dogs. By Walter Heape, M.A., F.R.S., Trinity College, Cambridge.

[*Received* 20 February, 1907.]

Introduction.

In the following paper I have confined myself to the facts presented by the records I have collected.

I do not propose here to enter into a detailed argument regarding the causes which influence the proportion of the sexes produced by various animals, but would preface my remarks with a very brief general statement of certain aspects of that problem, as they appear to me.

For generations it has been believed that the sex of an embryo is determined by extraneous forces exerted during the development of the embryo.

The subject has always excited great interest among breeders and there is a huge literature dealing with it. I have myself noted titles of over 600 papers and books in which a great variety of causes have been urged as influencing the sex of the offspring and numerous theories published on methods to be adopted in order to regulate the proportion of the sexes which are born.

A very large section of this mass of literature has been written on the assumption that sex is determined during embryonic life, that it can be and is normally determined in accordance with conditions which affect the growing embryo. But it seems clear, as I will show below, that both the ovum and the spermatozoan are themselves sexual, that the *latest*

moment at which the sex of the offspring can be determined is the time of fertilisation, and that no influence exerted subsequently can alter that sex.

If these statements be true therefore, it follows that all this portion of the literature may be disregarded from the point of view from which it was written; at the same time it appears to me to be of considerable value from another point of view and well worthy of attention.

The most recent writers on the subject claim that the sex of the generative products is governed by the laws of heredity, and, so far as I understand, the effect of extraneous influences on the sex of the progeny is wholly denied by them.

I find reason myself to believe, that while each ovum and spermatozoan in the generative glands contains within itself sex, which is probably determined by the laws of heredity, that the proportion of those male and female ova and spermatozoa which are developed and set free from the generative glands may be regulated by selective action, exerted in accordance with the resultant of a variety of extraneous forces. If this be true the proportion of living male and female ova and spermatozoa which are freed from the generative glands, and the proportion of the sexes of the offspring which result therefrom, will thus be influenced. It is this aspect of the problem with which I specially deal in the following paper; and it is in this connection that I find the literature, referred to above, of interest.

The very existence of sex demands that ova and spermatozoa or both should be themselves sexual, i.e. male, female, or hermaphrodite.

Recent researches by Wilson (*Journ. Exp. Zool.* vol. 3, 1906) demonstrate that the spermatozoa examined by him are histologically differentiated into two groups and it appears not improbable that these groups are male and female. If this be so, although histological evidence is wanting, there is no *prima facie* reason why ova should not be similarly differentiated, and the power some females possess to produce parthenogenetically in some cases functional males, in others functional females, points emphatically to that conclusion.

In this relation the research of Doncaster "on the maturation of the unfertilised egg and the fate of the polar bodies in the Tenthredinidae" (*Quart. Journ. of Mic. Sci.*, vol. 49, 1906) regarding the product of conjugation of certain portions of the divided polar bodies in parthenogenetic eggs, is of great interest, and is strongly suggestive, to my mind, that the ovum, in all animals, is capable of determining the sex of the progeny.

Apart from this latter point, to which I will refer below, it may I think be assumed that what is true for the spermatozoa

is at least true for the ova, and that both contain within themselves definite sexual characteristics.

Now regarding the product of these generative elements.

An animal is not necessarily purely male or female; on the contrary, notwithstanding the evidence adduced by Punnett, for instance ("Sex determination in Hydatina with some remarks on Parthenogenesis," *Proc. Roy. Soc.*, vol. 78, 1906) which seems to me probably capable of other interpretation, I will venture to maintain there is no such thing as a pure male or female animal, but that all contain a dominant and recessive sex, except those hermaphrodites in which both sexes are equally represented.

The appearance of recessive male characteristics in adult dominant females and of recessive female characteristics in adult dominant males, among unisexual animals, is of undoubted occurrence and not only from a structural point of view. I suggest therefore that this fact, together with various known examples of more pronounced dual sexuality; such as, for instance, the ability possessed by the male sexual gland of certain unisexual animals, under certain conditions, to produce ova (Potts "The modification of the sexual characters of the Hermit crab caused by the parasite Peltogaster," *Quart. Journ. of Mic. Sci.*, vol. 50, 1906); and the normal production of true hermaphrodites; is proof that all animals contain the elements of both sexes in some degree.

I should perhaps here point out that Potts' results do not show that the sex of the animal is changed by the parasite, but rather that the recessive sex present in the animal is thus stimulated. The structural modifications which accompany the changes in the generative glands indicate the close correlation of primary and secondary sexual characteristics.

In this relation the experiments of Bordage (quoted by Castle "The Heredity of Sex," *Bull. Mus. Comp. Zool. Harvard*, vol. 40, 1903) are of interest; they show that cutting back the apex of a young male plant of Carica pupaya just before the appearance of the male flower, may result in the growth of two branches from below the cut which bear female flowers and fruit. Also the observations of Strasburger (*Biolog. Centralblatt*, 1900) on the effect of rust fungus on the female flowers of Lychnis dioica, resulting in the development of stamens normally reduced to rudiments; and those of Meehan on the "Relation of heat to the sexes of flowers" (*Proc. Acad. Nat. Sci. Philadelphia*, 1882—1884), may be similarly interpreted. These observations are all indicative of the result of stimulation of the recessive sex, either directly, or indirectly on account of the functional degeneration of the dominant sex.

Much evidence advanced by Castle (*loc. cit.*) is of great interest in reference to this portion of the subject, and I regret that the

necessary brevity of this preliminary communication prevents me from analysing more fully his painstaking paper.

The assumption of male characteristics in old females and of female characteristics in old males is common knowledge and is evident not only in structural modifications but in modified mental traits. It would seem as if the recessive sex is here asserting itself, either on account of atrophy or hypertrophy of the dominant sex, either from exhaustion resulting from a long and active sexual life in paired individuals, or from a want of sexual exercise in unpaired individuals.

There are many examples of the existence of structural rudiments of the recessive sex, such as the clitoris of the female, the oviduct and mammæ in the male; while the occurrence of both structural *and* functional characteristics of the recessive sex in many unisexual animals from birth, is also well known, e.g. in the Pipe fish (Gudger "The breeding habits and the segmentation of the egg of the Pipe fish, Siphostoma Floridæ," *Proc. U.S. Nat. Hist. Mus.*, vol. 29, 1905), and there seems to me ample evidence for the conclusion that there is no such thing as a pure male or female.

From these premises it must be concluded, in order to fulfil the required conditions, that a male ovum is fertilised by a female spermatozoan and, *vice versa*, a female ovum by a male spermatozoan in all animals other than those produced parthenogenetically.

But if it is true that the adult animal is never purely male or female it may be argued that the sexual products are similarly constituted. In that case an ovum or a spermatozoan contains dominant male or female characteristics as the case may be, and recessive characteristics of the opposite sex. (Conf. Castle, *loc. cit.*)

In such case the possibility of infinite gradations of sexual differentiation in an individual would be vastly increased and, from the point of view of heredity, such complex conditions carry with them factors of the greatest importance.

For instance, the sexual selection which is undoubtedly, though unconsciously, exercised by civilised peoples, renders it probable that the recurrence in a nation, at long intervals of time (as suggested by Weininger "Sex and Character," 1906), of an increased or reduced proportion of so called effeminate men or of masculine women, or of the ebb and flow of a number of national characteristics intimately associated with the predominance of characteristics peculiar to one or the other sex (such as the desire for war, national hysteria, social sexual problems, &c.), may thus be accounted for. Weininger ably maintains, and it seems clear, that national characteristics of this nature are definitely correlated with the sum of dominant sexuality which exists at any one time.

Again it may be argued that, if both spermatozoan and ovum contain both male and female sexual elements, the dominant and recessive sex in the offspring would be assured even if an ovum was fertilised by a spermatozoan of the same dominant sex. This is no doubt true, but in that case it must be assumed that the individual resulting from such union would produce sexual products of only one dominant sex.

Such is manifestly not the case and I conclude that, so far as this argument is concerned, the probable existence of a dominant and recessive sex in both ovum and spermatozoan does not affect the question, but that it is essential that an ovum in which one sex is dominant should be fertilised by a spermatozoan in which the opposite sex is dominant.

These will be referred to below as male and female ova and spermatozoa.

Whether the sex of the embryo is determined by the ovum or by the spermatozoan is another matter. In the case of hermaphrodites it would appear that each of the sexual elements have equal power, but where the sexes are differentiated one or the other of the generative products must have a determining power.

In this latter case it may be held that a fight for supremacy takes place on the union of each spermatozoan with an ovum and that the dominant sex of the embryo is determined by the most powerful of the two.

But on this assumption the sex of the ovum and spermatozoan must, as a rule, be supposed to be of more or less equal power, and Mendelian laws indicate the certainty that in such case a far larger proportion of hermaphrodites would be produced than actually occur.

This appears to me sufficient reason for assuming that, in unisexual animals, either the ovum or the spermatozoan has a predominating influence, but which of the two is dominant I know of no conclusive evidence to show.

There is a mass of literature dealing with this aspect of the problem from a statistical point of view, one portion of it indicating marked influence of the male, the other no less marked influence of the female parent. I will not attempt an exhaustive analysis of these statistics here. They deal chiefly with the human species and with domesticated animals and are, for the most part, open to the objection that they are based only on living progeny and disregard those which are still-born or die young; for this reason they are not satisfactory for our purpose, but at the same time much may be learned from them.

Doncaster's and Castle's works show, it is true, that certain parthenogenetic ova give rise to male and others to female embryos and that in this case the power of determining the sex is contained

in the ovum; but the advent of a spermatozoan may upset all that and the sex of the sperm may always dominate that of the ovum. According to Castle (p. 199) there is some evidence of this among Rotifers, in which eggs under unfavourable conditions which form two polar bodies, develope parthenogenetically into males or if fertilised become "winter eggs" and produce parthenogenetic females. In this case the female element in the sperm would appear to dominate the male element in the ovum. But there are exceptions and the evidence does not appear to me to be at all conclusive since we are dealing with eggs capable of parthenogenetic development, and there are wide possibilities of differentiation in such eggs which are also capable of fertilisation. For instance, according to Punnett (*l. c.*) fertilisation of arrenotokous females is only possible a few hours after hatching.

Again, Bateson and Punnett's interpretation of their studies on Poultry (*Report to the Evolution Committee, Royal Society*, Pt. II., 1905) leads them to infer that sometimes the ovum and at others the sperm is responsible for sexual differentiation.

Thus it may be that for certain species of animals, or for certain individuals, the sex of the embryo is derived from the ovum while for others it is derived from the sperm, and that is as far as present evidence permits us to go.

But even if that be so, if the two are necessarily of opposite sex, the sex of the ovum has a regular relation to the sex of the embryo just as surely as if it conferred its own sex, and for the purpose of my future argument this is all it is necessary to assume.

On this assumption a female parent producing ova of one sex only will give birth to embryos of one sex, unless the male parent possesses no spermatozoa of the opposite sex wherewith to fertilise it, in which case the union will be barren. Düsing ("Die Regulierung des Geschlechtsverhältnisses bei der Vermehrung der Menschen, Tiere, und Pflanzen," *Jena Zeitschr.*, vol. 17, 1884) claimed that the statistical results he obtained from a study of the mating of thoroughbred horses, indicated the dominant influence of the male parent on the sex of the offspring. Any sire that usually produces spermatozoa of one sex only can be fertile, as a rule, only with mares which produce ova of the other sex, and to such an extent he determines the proportion of the sexes of the offspring for which he is responsible; but where sperm of both sexes is uniformly produced, the sire must be fertile with all mares producing ova, and, as only one ovum is produced by each mare, the responsibility for the sex of the offspring then lies solely with the female parent.

I think it will be found that a very large proportion of the evidence adduced to show the preponderating influence of the

male parent on the sex of the offspring may thus be explained; while statistically the father might be shown to be responsible, physiologically the mother controls the governing influence.

Normally it may be assumed that both sexes of ova and spermatozoa are present in the ovary and testis. Among most viviparous animals, however, but few ova ripen at one time, in many of them only a single one is dehisced; the necessities attending gestation having led to specialisation in this respect. On the other hand, having regard to the enormous numbers of spermatozoa produced per ovum fertilised, it seems that specialisation to the same extent has not occurred in the male and that both sexes of spermatozoa are as a rule presented; thus it follows that in these animals, as a rule, the sex of the embryo is solely determined by the mother, no matter whether that sex is derived from the ovum or the sperm.

Concerning the proportion of the sexes produced; it may well be that, in those females which shed all their ova the proportion of the sexes of these ova and, if they are fertilised, the proportion of the sexes of the young so produced, will be governed by Mendelian laws. But amongst animals which only produce during their life a small proportion of the ova contained in the ovary, in which from time to time, owing probably to a great variety of circumstances, a considerable number of these ovarian ova degenerate and are absorbed, the proportion of the sexes of the ova produced is surely directly dependent upon the causes which induce the degeneration of some and the ripening of other ovarian ova.

There can be little doubt that the proportion of the sexes produced by various species of animals, and by varieties of those species, is to some extent a racial characteristic; but from a study of the evidence before me I am induced to maintain that such proportion may be very largely influenced by a great variety of causes which exert their influence upon the male or female ovarian ova, causing one or the other to develope and ripen or to degenerate as the case may be. The same may be true for the testes of the male, but of this I have no evidence.

A study of the rabbit's ovary shows that two kinds of degeneration prevail, the one affecting first the follicle and subsequently the ovum, the other first the ovum and subsequently the follicle. I have interpreted the latter to mean that the ovum is unable to assimilate the nutriment offered to it, while the former, I judge, is evidence that, for some reason or other, either one or more ova develope at the expense of the others, or the nutriment available is insufficient for the maintenance of all the ova at that time ("Ovulation and degeneration of ova in the Rabbit," *Proc. Roy. Soc.*, vol. B. 76, 1905).

Although the causes which induce the degeneration of ova have not been surely demonstrated, I think it may unhesitatingly be accepted that nutrition plays a very important part therein; but whether it exerts a selective action as regards sex, whether it affects the proportion of male or female ova which ripen, there is, so far as I know, no conclusive evidence. On this subject of nutrition and sex there is again a large literature which it is impossible to present fairly here. Most of it is written to show that the sex of the embryo can be governed by the nutriment supplied to the mother during gestation and with this section, for reasons already stated, we have nothing to do; for the rest, almost all of it is based upon the supposed effects produced by the quantitative supply of nutriment presented to the mother.

There is much confusion about the whole of this section of the subject. For instance, in support of the view, very generally held, that more nutriment is required for the production of females than for males; it is argued that, as the adult female has greater capacity for storing nutriment than the adult male, this fact is evidence that more nourishment is required for her production. I think it is clear that the viviparous female has, broadly speaking, greater powers of storing nutriment than is possessed by the male. Her maternal functions require such special capacity and, though I will not give data here, I will add, there is conclusive evidence to my mind that she possesses it. But if it is so, that is no evidence that the ovum from which she is derived requires more nourishment for its development.

Again, the greater difficulty experienced in rearing male than female children is attributed by some observers to the better nourished condition in which girls are born; and many have argued, in one form or another, this is clear evidence that the mother needs an extra supply of nourishment to enable her to produce a girl. So far as this latter point is concerned perhaps the greater mortality among male infants is otherwise to be explained. But however this may be the point at issue is not affected thereby, for if nutriment has any effect at all upon the proportion of the sexes produced, it must be exerted on the ovum in the ovary; that is to say it is the capacity of the mother to supply the ovary with nutriment which must be taken into consideration. Now it does not at all follow that a female with exceptional powers of assimilating and of storing nutriment, or that a mother especially capable of producing well-nourished offspring, gives birth to an excess of females; indeed my own experiments indicate that the reverse, in many cases, is true. At the same time there are records of experiments which may, in my opinion, be interpreted to show that nutrition has a selective action on ovarian ova; it is on these lines I have myself been

working, not without success; and I hold that either quantitatively or, more probably, qualitatively this is true.

Of the various other agencies which it is claimed affect the proportion of the sexes born, such as in-breeding, cross-breeding, age, climate, temperature, &c.; such power as they have, and I think there is sufficient evidence to show they are potent agencies, must be exercised either as a selective agent on the ova and spermatozoa, while within the generative glands of the parents, or as a purely destructive agent on the freed products of these glands. As selective agents these forces may act directly on the ovarian ova or indirectly affect them by modifying the vitality of the whole generative gland, making it thus more or less capable of assimilating the nutriment with which it is supplied. By these means ova requiring an excess of, or a certain quality of nutriment, will have their needs supplied or they will degenerate; those most easily brought to maturity will ripen while others will fail to do so; the special vitality of some ova will cause them to thrive, certainly at the expense of and probably on, their less active neighbours.

The variation which exists in the physiological capacities of the adult male and female is surely represented in the sexual ovum. The marked difference in the death rate of males and females during famines, for instance (Lewis McIver, *Madras Census Report*, 1881, vol. 1, 1883), may well be reproduced among male and female ova in the ovary when that organ is subjected to homologous conditions; and such conditions may certainly be brought about in consequence of the active participation of one or other or many of the extraneous forces already alluded to.

Thus, so far as this portion of the subject is concerned I am disposed to maintain:

(1) that through the medium of nutrition supplied to the ovary, either by the quantity or by the quality of that nutrition, either by its direct effect upon the ovarian ova or by its indirect effect, a variation in the proportion of the sexes of the ova produced, and therefore of the young born, is effected in all animals in which the ripening of the ovarian ova is subject to selective action;

(2) that when no selective action occurs in the ovary the proportion of the sexes of ovarian ova produced is governed by laws of heredity.

With this very brief outline of my interpretation of the evidence before me regarding this section of a most intricate subject I must here content myself.

In the following pages are treated various breeds of dogs and indications are given of the exercise of certain forces which appear to affect to some extent the proportion of the sexes produced.

I am not aware that this has hitherto been done; the figures given are I think not without value and will, I hope, be thought worthy of record.

The Proportion of the Sexes in Dogs.

Darwin, in his *Descent of Man* (vol. 1, p. 304, 1871) records information he had obtained regarding the proportion of the sexes in Greyhounds. From 1857 to 1868, 6878 births were recorded, the proportion of males being 110·1 per 100 females.

The figures submitted to him showed very considerable fluctuation during different years, the extremes being in 1864, when 95·3 males were produced per 100 females, and in 1867, when the proportion of males was 116·3.

Further he states that several great breeders of dogs are unanimously of opinion that females are *produced* in excess.

Some years ago I collected statistics on this subject and in view of the opinion of the breeders above mentioned and of the interest now aroused in the sex problem it appears to me advisable to record the results obtained.

The figures Darwin published were those of births of a single breed of dogs recorded in the *Field*. But a dog-breeder does not necessarily keep all the offspring produced in a litter, there may be more produced than the mother can rear with advantage, in which case one or more puppies may be destroyed; or there may be weakly members of the litter which the breeder will certainly destroy; or there may be some puppies born dead.

Clearly then the proportions he arrived at were not necessarily the proportions of the sexes actually borne by dogs of this breed, and were certainly not so unless the foregoing sources of error were eliminated.

If it is true, as is suggested, that females are valued less than males, in case puppies are destroyed on account of the large size of a litter it would be the bitch puppies which would be so destroyed, and this custom might account for the opinion that females are produced in excess. On the other hand among human beings the mortality of young males is greater than that of young females; if the same rule obtains for dogs therefore it is to be expected that among weakly members of a litter, which are destroyed, males would predominate and Darwin's figures would be below and not above the average for males produced.

Again the proportion of the sexes in Greyhounds may be different from those in other breeds of dogs; there may be a racial variation in the proportion of the sexes produced; and in view of the application of Mendelian laws this fact would appear to be worthy of attention.

With regard to the records now presented. First, I have checked the figures supplied to Darwin by collecting the returns entered in volumes 7 to 11 of the *Greyhound Stud Book* for the years 1886—1892. Secondly, I have tabulated the returns for all breeds of dogs published in the *Stock Keeper*, *Kennel Register* for the years 1889—1891. Thirdly, I have abstracted the returns published in the *Stock Keeper* for particular breeds of dogs, for those years. Fourthly, I have collected information from certain breeders who keep accurate records, of the number of males and females actually born in a variety of breeds of dogs; and, as some of these latter records extend over a considerable period and give the results of the mating of individual dogs and individual bitches, year after year, I have been enabled to record the tendency of these individuals to produce a marked proportion of offspring of one or the other sex.

The Greyhound Stud Book.

Records from the *Greyhound Stud Book*, vols. 7 (1888) to 11 (1892) are summarised in Table I. The animals registered during that time are tabulated under the year in which they are born.

TABLE I.

Greyhound Stud Book. Registered births per year, 1886—1892.

Year	1886	1887	1888	1889	1890	1891	1892
Dogs	777	2278	1935	1923	1781	940	40
Bitches	666	1880	1628	1666	1475	813	36
Total	1443	4158	3563	3589	3256	1753	76
Dogs per 100 bitches	116·6	121·17	118·86	115·43	120·74	115·62	111·1

As the Table indicates, pups are not always registered the first or even the second year after they are born and for that reason the records for the years 1886, 1891, and 1892, in the Table, include only a part of the animals which have already been or eventually will be recorded for those years.

Probably, for the same reason, the records for 1890 are also incomplete, but judging from the totals obtained for 1887—1889,

but few remain to be added to that year's total and the results for the four years 1887—1890 may be taken as typical.

The proportion of dogs for these four years varies between 115·43 and 121·17, an average of 119·07; while if all the animals registered are included in the calculation the average works out at 118·5, as against 110·1 given by Darwin, a difference of 8·4 in favour of dog pups.

In Table II, the numbers are given in accordance with the month of birth, and, roughly, of the month of conception.

TABLE II.

Greyhound Stud Book. Registered births per month for years 1886—1892.

Month of birth	Dogs	Bitches	Total	Dogs per 100 bitches	Extreme variation during years 1887—1890. Dogs per 100 bitches	Difference	Mean of variation during years 1887—1890. Dogs per 100 bitches	Month of conception
Jan.	1031	805	1836	128·07	123—134	11	128·5	Nov.
Feb.	988	867	1855	113·96	95—127	32	111·0	Dec.
Mar.	1280	1127	2407	113·57	107—117	10	112·0	Jan.
Apr.	1610	1378	2988	116·84	111—127	16	119·0	Feb.
May	1685	1414	3099	119·16	111—124	13	117·5	Mar.
June	1326	1155	2481	114·8	112—121	9	116·5	Apr.
July	938	761	1699	123·26	95—130	35	112·5	May
Aug.	432	363	795	119·0	93—149	56	121·0	June
Sept.	202	182	384	110·99	96—130	34	113·0	July
Oct.	94	65	159	144·61	115—187	72	151·0	Aug.
Nov.	45	25	70	180·0	133—200	67	166·5	Sept.
Dec.	43	22	65	195·45	171—500	329	335·5	Oct.
Totals	9674	8164	17838	118·5	115—121	6	118·0	

According to Stonehenge (*The dog in health and disease*, 1887) the best time of year for breeding is from April to September, the cold of winter being unfavourable for the development of young puppies; but for sporting reasons Greyhounds are usually bred earlier in the year, because their age is reckoned from the 1st January and the earlier they are born the better chance they have in competition with their fellows of the same year. Thus, this Table shows that the four months, March to June, are the months during which most births are recorded and,

roughly, November to May is the time of year when conception usually takes place.

From March to June, when births are most frequent, the proportion of dogs per 100 bitches is remarkably constant, varying from 113·57 to 119·16, a difference of 5·59, the average being 116·29; whereas from July to February, when births are less frequent, there is a much wider variation, namely from 110·99 (September) to 195·45 (December), a difference of 84·46, the average being 122·1 dogs per 100 bitches.

In only three of these months, viz. August (119·0), September (110·99), and February (113·96) is the proportion of dogs lower than that recorded for any of the months, March to June; in all other months the proportion of dogs is higher, especially in the four winter months from October to January, when the proportion ranges from 144·61 to 195·45, the average being 132·27 dogs per 100 bitches.

The column in Table II showing the extremes of variation for the years 1887—1890 indicates a very similar result. The lowest proportion of dogs recorded for the four months March to June varies from 107 to 112, a difference of 5, while the highest proportion varies from 117 to 127, a difference of 10. From July to February, however, the lowest figures range from 93 to 171, the highest figures from 127 to 500.

In the same way the differences range from 9 to 16 from March to June, and from 11 to 329 from July to February, while the greatest differences occur during the winter months, October to December, when the highest proportion of dogs is born.

The mean of the variation during the years 1887—1890 shows this result more markedly. In this column it is seen that in all months from February to July less than 120 dogs per 100 bitches are registered, while in all from August to January, with the single exception of September, the proportion of dogs is more than 120.

An examination in detail of my figures shows that throughout each year, month by month, there is almost invariably a marked preponderance of dogs recorded. The only months in which bitches predominate occur irregularly as follows: July, 1888, 95 dogs; February, 1889, 95; August, 1889, 93; September, 1890, 96 per 100 bitches; while in a series of years there is no month which shows a preponderance of bitches.

Again, while the annual total invariably shows a higher proportion of dogs than bitches there is no year in which this is markedly the case, the extreme variation of the totals for 1887—1890 being 6.

The year in which only 115 dogs were recorded was in 1889, when the proportion of dogs fell especially low in both February and August of that year.

Although below I shall show that accurate records of the sex of puppies *born* prove that, in a variety of breeds, a still higher proportion of dogs is produced than is recorded in these tables, I think it is nevertheless justifiable to conclude that the figures now dealt with are not widely misleading and that they demonstrate sufficiently clearly the broad conclusions I have drawn from them, namely:

In spite of the fact that it must be assumed all births are not recorded, the marked increase in the proportion of dogs registered as born in the winter months is very striking, and I am of opinion it may be assumed that conception during the six months June to November, and especially during the last four of these months, August to November, is more highly favourable to the production of male than of female Greyhounds under the conditions of breeding now practised.

The fact that the preponderance of births of dogs over bitches is greater at one time of the year than at another, and that an excessive preponderance of male births is associated with a low birth rate, during the winter months, is worthy of notice in its relation to the normal breeding time of these animals, i.e. to the time when the generative organs are in their most active condition, and therefore in relation to the view that the sex of the ova produced is governed by selective action.

The Stock Keeper, Kennel Register.

The records contained in the *Kennel Register* are open to the same objection which has been admitted for the *Greyhound Stud Book*, namely, that all pups born are not necessarily registered; but, as a comparison of these returns with breeders' Schedule returns (given below) will show, the objection is certainly not a weighty one in this case. I have, therefore, abstracted details for a series of breeds, of which there are sufficient entries, for the years 1889—1891, Table IV, and also added the annual totals of every entry made for all breeds for those years, Table V. The returns in Table IV have been classified into Large dogs and Terriers, and it is seen that while the dogs born per 100 bitches among Terriers is 113, among Large dogs it rises to 117·51. At the same time it is shown that whereas among Terriers the pups per litter work out at an average of 5·4, among Large dogs the litters are considerably bigger and average 7·5 pups. The class of dog with the highest fertility per litter thus appears to produce the largest proportion of dog pups.

The results obtained for the Large dogs are dominated by Collies, St Bernards, and Spaniels; those for Terriers by Bull, Irish, and Fox Terriers; to test this point further I have isolated these breeds, with the following results:

TABLE III.

Stock Keeper, Kennel Register, 1889—1891.

Breeds	Dogs	Bitches	Total	Dogs per 100 bitches	Litters	Pups per litter
Collies..... St Bernards.. Spaniels	5040	4290	9330	117·48	1247	7·48
Bull Terriers Irish Terriers Fox Terriers.	2216	1986	4202	111·58	752	5·59

The difference is 5·9 and, from these figures, it seems permissible to conclude that the largest number of dog pups is obtained amongst the largest litters.

It is true that individual entries such as, for instance, English White Terriers, Black and Tan Toy Terriers, &c., and Bulldogs, do not conform to this conclusion, but in each of these isolated cases we are dealing with very small numbers and for that reason a detailed comparison is not justified. As a class distinction the comparison I have made is, I think, justifiable and I may add that the figures given below, derived from the Schedules sent to breeders, in which an accurate record of each litter is given, bear out this conclusion, though the difference is less, being 2·63.

Taking each breed individually there is some evidence that the production of a high percentage of males is associated with in-breeding. Many breeders hold a strong opinion that this is the case; I have not sufficient evidence here to show the fact, but there are some indications of its probability.

Concerning fertility, it is remarkable that the average number of pups per litter is so closely in accord with the actual size of the breed of dog concerned (Table IV). From Bloodhounds to Toy Terriers there is an almost regular correlation between size and fertility per litter.

In the absence of assurance that all pups born are registered, one is naturally disposed to imagine it is possible that a larger proportion of pups are destroyed among small breeds than among large breeds of dogs, that the relation shown here is an artificial one due to the necessity of reducing the strain of motherhood

Table IV.

Stock Keeper, Kennel Register, 1889—1891.

Breed	Dogs	Bitches	Total	Dogs per 100 bitches	Litters	Pups per litter
Bloodhounds	90	71	161	126·76	16	10·06
Setters.....	81	84	165	96·43	19	8·68
St Bernards.....	923	804	1727	114·8	208	8·53
Newfoundlands.....	193	162	355	119·13	42	8·45
Retrievers	78	62	140	125·8	18	7·7
Mastiffs	171	159	330	107·55	43	7·67
Collies & Sheep dogs	3671	3106	6777	118·19	917	7·39
Spaniels	446	380	826	117·37	122	6·77
Bulldogs.....	279	220	499	126·82	79	6·32
Totals for large breeds	5932	5048	10980	117·51	1464	7·5
Airedale Terriers ...	114	95	209	120·0	31	6·74
Bull Terriers	375	329	704	113·98	111	6·34
Irish Terriers	1209	1114	2323	108·53	379	6·13
Bedlington Terriers.	100	104	204	96·15	35	5·83
Scotch Terriers	224	195	419	114·87	76	5·51
Dandie-dinmont do.	158	137	295	115·33	56	5·3
Black & tan, and Manchester do. ...	184	165	349	111·51	74	4·72
Welsh Terriers	21	21	42	100·0	9	4·6
Fox Terriers	632	543	1175	116·39	262	4·48
English white do. ...	106	78	184	135·9	42	4·38
Black & tan Toy, Yorkshire, & Skye Terriers	196	156	352	125·64	83	4·24
Totals for Terriers...	3319	2937	6256	113·0	1158	5·4
Totals for all breeds	9251	7985	17236	115·85	2622	6·57

among small dogs. But this is not so; the details given below, of Schedule returns, show a similar relation between size and fertility. The figures there given are not identical with those we are now considering but the difference, on the whole, is not an increase in the pups per litter of small breeds, it is a decrease in the case of large breeds; a difference which may be accounted for to some extent by the very much smaller numbers there dealt with (individual variation), but probably chiefly to the fact that the bulk of the Schedule returns deal with animals which are especially finely bred.

From a comparison of the whole of my figures I am tempted to suggest that, if dealt with in greater numbers, returns of all breeds of dogs would show the rate of fertility coincident with the degree of specialisation from the parent type.

It is possible there is correlation between the size of the mother and the total bulk of the young born, it is also possible that large dogs do not produce young so often as the smaller breeds and that therefore the latter may well produce fewer at each gestation. On these points I have no conclusive evidence, all that can be asserted is that there is a definite relation between the size of different breeds of dogs and the average number of pups produced per litter.

Besides the above breeds there are a considerable number of others, the pups of which are from time to time recorded, some of these are large, some small dogs. These I have added to the records of special breeds and have collected the totals for each of the three years 1889—1891 (Table V) in order to test the degree of regularity of these records.

TABLE V.

Stock Keeper, Kennel Register. All Breeds, 1889—1891.

Year	Dogs	Bitches	Total	Dogs per 100 bitches	Litters	Pups per litter
1889	3591	3059	6650	117·39	1037	6·41
1890	3415	2959	6374	115·41	997	6·39
1891	3294	2832	6126	116·31	964	6·35
Totals	10300	8850	19150	116·38	2998	6·39

I think it must be admitted that the close approximation of the total results for each year is very remarkable. The greatest variation under the heading dogs per 100 bitches is 1·98, and under pups per litter ·06. This yearly comparison is far more regular than the yearly records for Greyhounds (Table I), and I am disposed to think the reason for this is that the breeding time is not artificially controlled to the same extent as we have seen is the case for Greyhounds.

The only breed dealt with in the *Kennel Register* returns which is at all comparable to the Greyhound returns, so far as the number of pups is concerned, is "Collies and Sheep dogs"; I have therefore tabulated details of the latter breeds to show monthly returns of births, &c.

The result is given in Table VI and it is seen to be, in some respects, different from that obtained from the *Greyhound Stud Book*.

March to June are the months in which the greatest number of births is recorded for Greyhounds, while for Collies most births are recorded from May to August. As I have already stated the purpose for which most Greyhounds are bred is accountable for the period of greatest fertility and it may be assumed that in this respect the natural breeding habits of Collies are much less interfered with. For the same reason, while for Greyhounds the months of August to December show a very low rate of fertility, there is no such great variation for Collies at any time of the year, though the birth rate from October to December is the lowest of the year.

Thus, while the Greyhound records, years 1886—1892, show only 65 births in December against 3099 in May, the lowest record for Collies, years 1889—1891, is 410 births in November and the highest 796 in July.

That the rate of fertility (pups per litter) is not responsible for the seasonal variation in the number of Collies born is clear, and a glance at the litters will show that, for Collies, there is a gradual falling off in the number of litters from the month in which most births are recorded to the end of the year, and a gradual rise from the beginning of the year to the date of the maximum births.

Concerning the sex of the pups produced. The totals for Greyhounds show a proportion of 118·5 dogs and for Collies 118·19, a very close agreement. Not less remarkable is the similarity in the difference between the variation of this percentage each year; that for Greyhounds, 1887—1890, being 6 (115—121), that for Collies, 1889—1891, being 7 (115—122).

It is the monthly returns of the proportion of dogs where the greatest difference between the records of these breeds is apparent.

TABLE VI. *Stock Keeper, Kennel Register. Collies, births per month for years* 1889—1891.

Month of birth	Dogs	Bitches	Total	Dogs per 100 bitches	Extreme variation during years 1889—1891. Dogs per 100 bitches	Difference	Mean of variation during years 1889—1891. Dogs per 100 bitches	Litters	Pups per litter	Month of conception
Jan.	273	203	476	134·48	123—150	27	136·5	62	7·67	Nov.
Feb.	265	205	470	129·27	112—149	37	130·5	64	7·34	Dec.
Mar.	302	252	554	119·84	119—121	2	120·0	76	7·29	Jan.
Apr.	314	268	582	117·16	110—123	13	116·5	80	7·27	Feb.
May	395	346	741	114·16	85—138	53	111·5	103	7·2	Mar.
June	367	315	682	116·5	95—144	49	119·5	95	7·16	Apr.
July	438	358	796	122·35	110—138	28	124·0	103	7·73	May
Aug.	435	328	763	132·62	116—147	31	131·5	102	7·48	June
Sept.	235	241	476	97·51	83—117	34	100·0	63	7·5	July
Oct.	229	185	414	123·78	106—145	39	125·5	56	7·39	Aug.
Nov.	210	200	410	105·0	94—115	21	104·5	53	7·73	Sept.
Dec.	208	205	413	101·46	96—112	16	104·0	60	6·88	Oct.
Totals	3671	3106	6777	118·19	115—122	7	118·5	917	7·39	

The great excess of dogs produced by Greyhounds in the winter months is not seen in Collies, on the contrary it is during those months that the lowest proportion of dogs is recorded. My own interpretation of the cause of this difference is, that while amongst Greyhounds most of the few litters born at this period were probably conceived, in consequence of some carelessness of the kennel-man, by bitches in training and not carefully nurtured for breeding, amongst Collies the conception of pups born during these months takes place in bitches which are not so affected but which, on the contrary, are probably in specially good condition (i.e. July to October). In a future communication I propose to submit evidence in favour of this view.

A comparison of the columns showing the extreme variation of dogs per 100 bitches born and of the difference in these proportions, for Collies (Table V) and for Greyhounds (Table II) shows, that while among Collies the greatest difference occurs as a rule in those months in which the largest number of pups are born, in Greyhounds the greatest difference is associated with the fewest births. This may be interpreted as indicative that the latter are more susceptible to annual variation of climate, temperature, &c., than the former, an interpretation which is perhaps strengthened when the structure and habits of the two breeds and the life they lead are compared.

Evidence in favour of this interpretation I must also defer to a future communication.

Breeders' Schedule Returns.

In these returns the breeders applied to supplied me with details of the sex of every pup produced in each litter whenever that was possible. In a few cases still-born pups were produced in a condition which did not admit of sex determination; in these cases, and in all others regarding which there was any doubt, the litters are not included in the figures given below.

The totals for each breed are given in Table VII.

As in Table IV, I have again divided the breeds into Large dogs and Terriers. The pups per litter for the Large dogs, as returned in the Schedules, are ·57 smaller than those given in the *Kennel Register* (Table IV), for the Terriers they are practically the same. Here again it is shown that the bigger dogs have the larger litters and, with the exception of Pointers, this is as true in detail as was seen in the *Kennel Register* records. There is undoubted correlation between the size of the animal and its fertility per litter.

The pups per litter for Collies and Mastiffs are closely approximate in both Tables, while the Schedule returns for

Bloodhounds show 1·54 fewer pups per litter than the *Kennel Register* gives. Basset hounds and Pointers are not represented in the figures given from the *Kennel Register* and it is these breeds which are chiefly responsible for the lower average fertility of the Larger dogs in the Schedule returns. The number of litters dealt with for Basset hounds is exceptionally large and the returns very complete, while for Pointers the returns are exceptionally incomplete and the litters available for my purpose but a small proportion of the whole sent to me. Among Terriers, Scotch Terriers show about the same rate of fertility in both Tables, while the Schedule returns for Irish Terriers are ·7 below, and for Dandie-dinmonts ·46 above those of the *Kennel Register*.

Table VII.

Summary of Schedule Returns.

Breed	Dogs	Bitches	Total	Dogs per 100 bitches	Litters	Pups per litter
Bloodhounds	111	85	196	130·59	23	8·52
Mastiffs	86	88	174	97·73	22	7·91
Collies	60	50	110	120·0	15	7·3
Basset hounds	198	136	334	145·59	54	6·18
Pointers	26	26	52	100·0	11	4·73
Totals for large dogs	481	385	866	124·93	125	6·93
Dandie-dinmonts	73	71	144	102·82	25	5·76
Irish Terriers.....	65	49	114	132·65	21	5·43
Scotch Terriers	116	84	200	138·09	37	5·4
Dachshunds	214	175	389	122·28	73	5·33
Skye Terriers.....	32	24	56	133·3	11	5·09
Various	10	14	24	71·43	5	4·8
Totals for Terriers	510	417	927	122·3	172	5·39
Totals for all breeds	991	802	1793	123·57	297	6·04

The average of pups per litter of all breeds is ·53 in favour of the *Kennel Register*. In other words the rate of fertility shown in the latter is 8 % above what is recorded in the Schedules. It is the Basset hounds and Bloodhounds which are chiefly re-

sponsible for the reduction, and as the other breeds show very similar results there is good reason to believe that the litters recorded in the *Kennel Register* very generally include all the pups born.

If this assumption is correct a comparison of the proportion of dog and bitch pups born is of increased interest.

In both classes, both Large dogs and Terriers, the proportion of dogs born is considerably greater in the Schedule than in the *Kennel Register* records, namely for Large dogs 7·42, for Terriers 9·3, and for the totals 7·72 greater. The difference being specially marked for Terriers.

Taking particular breeds in the Schedules, as compared with the same in the *Kennel Register*, Bloodhounds show + 3·83, Collies + 1·81, Mastiffs − 9·82, Scotch Terriers + 23·22, Irish Terriers + 24·12, Dandie-dinmonts − 12·51

The only breeds in the Schedules showing fewer dog than bitch pups are Mastiffs with 97·73 and various Small dogs with 71·43 dogs per 100 bitches; while in the *Kennel Register*, Setters 96·43, and Bedlington Terriers 96·15, are the only breeds in that category.

In the case of neither the Mastiffs, Setters, or Bedlington Terriers can it be claimed that either fertility or the number of litters included in the calculation, affect the proportion of the sexes produced.

From the totals it appears that the Schedules show a greater proportion of dog pups than either the *Greyhound Stud Book* or the *Kennel Register*, and, while making allowance for racial variation, it would seem probable that the opinion expressed by Greyhound breeders, recorded by Darwin, that bitches are produced in excess, is not true; on the contrary such difference as does exist in these three returns would indicate that, as in human beings, young males are more difficult to rear than females, and that there is an excess of deaths among young dog pups.

The Schedule returns again show that, taken as a whole, the larger breeds of dogs with the greater fertility produce a larger proportion of dog pups.

The difference is not so great as was shown by the *Kennel Register* records, being only 2·63, but still it exists. No such regular difference, however, can be shown for individual breeds in Table VII, and it seems probable there are not a sufficient number of litters among these Schedules to admit of a fair comparison with those detailed in Table IV on this point.

As regards the effect of in-breeding on the proportion of the sexes produced, the most marked instance among my records is that of Basset hounds. A very large proportion of the litters recorded for this breed came from one kennel, that of the late

Sir Everett Millais, whose finely bred strain of this breed was well known. Bloodhounds, again, have a high proportion of dog pups and they are for the most part highly bred in this country. For the rest, Bulldogs, Retrievers, Scotch, Skye, Irish, and English White Terriers, I have no certain information. Taken as a whole, however, the animals treated of in the Schedules are probably more finely bred than those recorded in the *Kennel Register*, and the proportion of dog pups in the former is considerably greater than in the latter; thus, such evidence as I have is in favour of the view that in-breeding tends to the production of an increased proportion of males.

In the Schedules submitted to breeders information was asked about feeding and the condition of individual bitches, at the breeding time and during gestation, in order to attempt to discover whether "condition" at the time of conception showed any marked effect on the proportion of the sexes born. The descriptions given were usually "good" or "very fair," &c.; no detailed information was supplied, and nothing was shown which could in any way be interpreted as affecting the proportion of the sexes born.

The length of gestation was also recorded for 278 litters. This detail was asked for to check the opinion very generally held by breeders of stock, that when the period of gestation is prolonged beyond the normal time the produce are generally of the male sex.

I have divided the period of gestation into three divisions, making allowance for errors of calculation, which I have assumed are but small on the side of short gestation and mostly due to retarded fertilisation of the ovum *after* impregnation, thus:

(1) a short gestation period, from 53 to 61 days; in which there are 69 litters recorded with an average of 117·82 dogs;

(2) a normal gestation period, from 62 to 65 days; in which there are 194 litters with an average of 130·98 dogs, and

(3) a long gestation period, from 66 to 69 days; in which there are 15 litters giving an average of 140·48 dogs.

On the whole the results undoubtedly bear out the popular opinion, the totals for each division showing a gradual increase of male births as the period of gestation is prolonged.

In the latter division the litters recorded are few and the individual results very various, but in the first division this is not so and yet there is a marked difference in the proportion of dog pups between the first and second divisions.

In these returns it is remarkable that Bloodhounds are represented under almost every day both of the short and long periods of gestation. Altogether, no less than 11 litters of Bloodhounds out of a total of 22 recorded, that is 50 %, were produced outside the normal period.

TABLE VIII. *Schedule Returns. Proportion of sexes and length of gestation.*

Days of gestation	Dogs	Bitches	Total	Dogs per 100 bitches	Litters	Pups per litter	Breeds and number of litters
53	5	4	9	125·0	1	9	Bloodhound
55	6	3	9	200·0	1	9	Bloodhound
56	3	3	6	100·0	1	6	Dachshund
57	6	6	12	100·0	3	4	Dachshund (1), Scotch Terrier (2)
58	30	24	54	125·0	8	6·75	Bloodhound (1), Mastiff (1), Scotch Terrier (5), Various (1)
59	62	46	108	134·78	15	7·2	Bloodhound (3), Mastiff (3), Collie (1), Dachshund (1), Scotch Terrier (4), Dandie (1), Irish Terrier (1), Various (1)
60	45	39	84	115·38	15	5·6	Bloodhound (1), Mastiff (1), Basset (2), Collie (1), Dachshund (3), Scotch Terrier (4), Dandie (3)
61	81	77	158	105·19	25	6·32	Bloodhound (2), Mastiff (2), Dachshund (11), Dandie (9), Irish Terrier (1)
Totals (1)	238	202	440	117·82	69	6·38	Large dogs (20), Terriers (49)
62	135	98	233	137·75	41	5·68	All breeds
63	386	293	679	131·74	111	6·12	
64	67	50	117	134·0	20	5·85	
65	63	56	119	112·5	22	5·41	
Totals (2)	651	497	1148	130·98	194	5·92	Large dogs (81), Terriers (113)
66	11	12	23	91·6	5	4·6	Bloodhound (1), Collie (2), Dachshund (1), Various (1)
67	30	16	46	187·5	6	7·6	Bloodhound (1), Mastiff (1), Basset (1), Dachshund (2), Scotch Terrier (1)
68	9	3	12	300·0	1	12·0	Bloodhound
69	9	11	20	81·81	3	6·6	Bloodhound (1), Scotch Terrier (1), Skye Terrier (1)
Totals (3)	59	42	101	140·48	15	6·73	Large dogs (8), Terriers (7)
Totals	948	741	1689	127·93	278	6·07	Large dogs (109), Terriers (169)

This breed then is specially adapted for checking the general result given above and I have set it forth in Table IX.

TABLE IX.

Schedule Returns. Bloodhounds, gestation and sex of pups.

Days of gestation	Dogs per 100 bitches	Litters	Pups per litter
(1) 53—61	125·64	9	9·7
(2) 62—65	138·46	9	6·8
(3) 66—69	157·14	4	9·0

Here is a very striking confirmation of the view advanced. The returns of the pups per litter in Tables VIII and IX do not indicate that the size of the litter has anything to do with prolonged gestation; the litters produced both in divisions (1) and (3) in each of these tables are bigger than those in division (2), the normal gestation period, so it does seem as if the excess of male embryos in the uterus is directly responsible for the delay in parturition.

I do not of course maintain that the length of gestation has any influence whatever on the sex of the young born, these results only show the tendency to prolong gestation when an excess of male embryos are present in the uterus.

The association of a longer gestation period with the production of an excess of males may be regarded as evidence either that male embryos require a longer uterine life for their full development or that they are born, when possible, in a more advanced condition than the females. This is a question of considerable interest in relation to the physiology of breeding, and also regarding various sexual differentiations.

Another point of interest with regard to Table VIII is that whereas 20 litters of Large dogs (18·35 % of the whole) and 49 litters of Terriers (29 %) have a shorter gestation than normal, 8 litters of Large dogs (7·34 %), and 7 litters of Terriers (4·14 %) experience a longer gestation than normal.

Thus, while on the one hand abnormally short gestation is more usual than abnormally long gestation for both classes of dog, the proportion of Terriers is greater than that of Large dogs for short gestation, and the proportion of Large dogs greater than that of Terriers for long gestation periods.

Table X.

Schedule Returns. Proportion of dog pups produced by individual parent

Breed	Dogs per 100 bitches. Average for breed	Sire No.	Litters	Dogs per 100 bitches	Bitch No.	Litters	Dogs per 100 bitches
Basset hounds ...	144·58	1	13	155·17	4	6	161·5
		5	6	131·5	15	6	122·2
		14	5	100·0	17	4	130·0
		3	4	200·0	28	4	266·6
		6	4	133·3			
		10	4	133·3			
Bloodhounds ...	130·59	3	9	140·0			
		1	5	182·35			
		4	5	104·0			
		2	4	92·3			
Collies	120·0	3	4	120·0	7	5	118·75
Mastiffs	97·73	1	13	91·3	1	4	153·3
Scotch Terriers..	138·09	3	5	141·6	5	7	104·5
Skye Terriers	133·3				1	4	466·6
Irish Terriers	132·65	3	8	160·0	1	7	72·72
					2	4	320·0
Dachshunds.....	122·28	1	19	170·27	5	5	144·4
		2	19	108·3	6	5	112·5
		3	9	88·8	12	5	100·0
Dandie-dinmonts	102·82	1	6	68·75	2	4	116·6
		2	4	84·61			
Totals.....		19	146		14	70	

I have taken advantage of the fact that, in the Schedules returned to me, the performance of each sire and bitch is recorded for each litter, to test the tendency of individual male and female parents to produce a marked proportion of offspring of one sex. Only those cases are recorded in which the sire or the bitch have been concerned with four or more litters and the results are compared with the average obtained for the breed to which each animal belongs (Table X).

Of the six Basset hound sires one has got 44 fewer and one 56 more dog pups than the average, whilst the four bitches show great variation and one has 122 dog pups above the average.

Of the four Bloodhound sires one has 52 more and two others 38 and 26 fewer dog pups than the average; there are no bitches of this class recorded as having produced four litters.

A single dog and bitch among Collies produce about the average.

Of Mastiffs there is one sire responsible for more than half of the whole litters recorded in Table VII for that breed, and the low percentage of dog pups he is responsible for dominates the total results. A single Mastiff bitch, on the other hand, produces 56 more dog pups than the average for the breed.

Only one Scotch Terrier sire is recorded with about the average of dog pups, while a single bitch falls short in her produce of dogs by 34.

Only one Skye Terrier bitch is recorded and the proportion of males she produced was 333 above the average.

Of Irish Terriers there is one sire and two bitches, the latter with a proportion of dog pups of 60 less and 188 more than the average, while the former has 28 to his credit.

Dachshunds again are very variable, especially the sires, of which there are three, varying from 88·8 to 170·27 dogs, while the three bitches show variation from 100·0 to 144·4 dog pups, the average for the breed being 122·28.

Amongst Dandie-dinmonts two sires give extraordinarily low results, 34 and 18 less than the exceptionally low average for the breed (102·82); the single bitch whose produce is recorded shows 14 more than the average of dog pups.

Thus of the total number of litters (297) recorded in Table VII, 146 (or 49·16 %) are got by 19 sires, and 70 (or 23·57 %) borne by 14 bitches.

Of these 19 sires, 15 show a variation of 10, 9 a variation of 20, 7 of 30, and 2 of 50 from the average. Of the 14 bitches, 12 show a variation of 10, 10 of 20, 6 of 30, and 5 of 50 from the average. It is therefore clear that the bitches show a much higher proportion of variation than the sires.

The numbers concerned are of course too small to allow of

wide generalisations, but there is evidence enough to show, as for instance in the case of Mastiffs, that the sire does also exert influence, and therefore that, if fertilisation of the ovum is effected by sperm of the complementary sex, a large proportion of the sperm produced by this animal must have been of one sex.

Finally, I have abstracted figures to test the opinion, held by many breeders of stock, that while in some years males are produced in marked excess, in others females predominate.

The figures at my disposal are far too few to admit of elaborate analysis but, taking Basset hounds and Dachshunds as representative of the two classes of dogs, I find that, during the 16 years Mr Millais bred Basset hounds, dog pups were produced in excess 11 years and bitches 1 year, while in 4 years the sexes were equal; and during the 11 years Mr Mudie bred Dachshunds, dog pups were in excess 6 years, bitch pups 4 years and the sexes equal 1 year. The racial tendency to produce a greater or less proportion of one sex, to which I have referred above, no doubt influences this comparison; Basset hounds produce a very much larger proportion of dog pups, on an average, than is the case with Dachshunds (Table VII), so it is not surprising to find a more even balance, per year, among the latter.

It is of special interest to note that, taking 9 years for which I have results from both kennels, only two of them show widely divergent results, and that in three consecutive years the results are: for (1), both kennels produced a small excess of bitch pups; for (2), a specially large proportion of dog pups were born in both, Mr Millais' results showing 180, Mr Mudie's 380 above the average; while for (3) there is a similar result, Mr Millais breeding 123·4 and Mr Mudie 162·5 above the average.

It is quite possible this is purely a chance coincidence and I don't attribute any great importance to it. The methods of feeding and housing dogs in large breeding kennels must eliminate much of the effect of variation in the seasons which might be supposed to exert influence.

Trustworthy records of the breeding of farm stock would supply what is needed to test this view and it is unfortunate that they are so difficult to obtain regularly and on a sufficiently large scale. For pheasants it is, I think, undoubtedly true that there is a marked difference in the proportion of cocks and hens driven to the guns in different years, and I am strongly disposed to believe there is truth in the popular belief.

Conclusions.

We have dealt with 19916 dog pups, 16951 bitch pups, a total of 36867 pups, of which the proportion of dogs per 100

bitches is 117·49. Nearly 50 % of these pups are Greyhounds (17838), with 118·5 dogs per 100 bitches, and no other breed dealt with is represented in anything like the same numbers; Collies with 6777 pups are the nearest and the proportion of dogs per 100 bitches in this breed is 118·19.

Apart from Greyhounds the returns deal with a variety of breeds and if details of all Large dogs are abstracted therefrom it is seen that of the total pups recorded (11846) 6413 are dogs and 5433 bitches, i.e. there are here 118·04 dogs per 100 bitches. Thus there is a very remarkable approximation in the proportion of the sexes produced by Greyhounds and Collies or by Greyhounds and the other Large dogs, taken as a whole, with which we have dealt.

The Terriers, taken as a whole, give a somewhat different result. Of these we have a total of 7183 pups, 3829 dogs, and 3354 bitches, giving 114·16 dogs per 100 bitches. A difference of four is not a wide variation, especially when the numbers dealt with are considered. Still there is this difference and I am disposed to think a more extensive series of data will demonstrate that there is a distinct racial variation in the proportion of the sexes produced by these two classes of dogs.

Again there is wide diversity in the results obtained for different breeds of both Large dogs and Terriers. The numbers dealt with are too small for safe generalisation, but the results are so marked in several cases that I believe racial variation will be found to exist between different breeds as well as between different classes of dogs.

Greyhounds. The data supplied to Darwin for Greyhounds gave 110·1 males per 100 females during the years 1858—1868, as against 118·5 in the above records 1886—1892. It is possible that in-breeding in these later years has had some effect in the direction of an increase in the proportion of dog pups born, but in the absence of assurance that all pups born were recorded by Darwin's informants, it seems probable that the difference is chiefly due to neglect of this source of error.

The returns now presented show the proportion of dogs born each year (Table I) and the proportion born per month for all these years jointly (Table II).

It is seen that most Greyhounds are born during certain months, March to June, and that the proportion of the sexes born then varies but little.

During every month in a series of years there is a preponderance of dog pups born, but during October to December, when the fewest pups are born, the proportion of dog pups is at its highest. The conclusion is drawn that conception during August to November is especially favourable to the production of dog

pups among Greyhounds under the conditions of breeding now practised, and this result is attributed to a selective action on the ova produced at this time.

Collies. The above returns are compared with similar ones obtained for Collies (Table VI). The latter show much less variation in the proportion of litters produced at different times of the year, the breeding of these animals being conducted much more in accordance with the natural breeding time for the species. Still in Collies there is a marked increase of births from May to August, and from October to December is the season when fewest births occur.

This result is due to the number of litters produced and not to any variation in the rate of fertility per litter.

The returns for Collies show no evidence that conception at any particular time of year affects the proportion of the sexes born; they rather indicate, if my supposition is correct, that when the animals breed at a time which is unfavourable for the rearing of the pups, special care is exercised.

Kennel Register and Breeders' Schedules. Data obtained from the *Kennel Register* for the years 1889—1891 (Table IV) are checked by information derived from Schedules filled up by breeders, in which latter returns accurate details are supplied for all the litters there dealt with (Table VII). In both Tables details are given for each breed dealt with and these are again classified under headings of Large dogs and Terriers. It is found that the fertility per litter is the same for Terriers in both the *Kennel Register* and the Schedules, while the latter show ·57 smaller litters for Large dogs. On the whole it may be assumed that the *Kennel Register* very generally includes all pups born. Where this is not the case it would appear that still-born pups or pups destroyed on account of weakness, which are not recorded in the *Kennel Register*, are usually of the male sex, since there is a considerably higher proportion of dog pups recorded in the Schedules than in the *Kennel Register*.

It is highly probable that the animals included in the Schedule returns are more in-bred than are those entered in the *Kennel Register*, and that this fact may account for some of the excess of male births recorded in the former. There is not wanting evidence from other sources that in-breeding is associated with the production of a high proportion of males. The bulk of the data at my disposal for dogs is not of a character which admits of wide generalisation on this point; there is, however, some evidence in the Schedules that an excessive production of males is associated with in-breeding and the details given of Bloodhounds may be said to be strongly in favour of this view.

In both these returns the Large dogs are found to produce

a higher proportion of males than the Terriers (compare Table III). It is also found that both support the view that there is almost regular correlation between the number of pups of the average litter for each breed and the size of the dog producing it; the larger dogs producing the larger litters.

Thus it would seem to be true that a bigger proportion of males is produced in the larger litters, or, as stated above, that large dogs have a racial tendency to produce an excess of dog pups.

It is suggested that the rate of fertility in different breeds is probably coincident with the degree of their specialisation from the parent type.

The annual returns for all breeds dealt with in the *Kennel Register* (Table V) show a remarkable regularity both in the proportion of the sexes born and in the fertility per litter.

The popular belief that there is a tendency to prolonged gestation when the embryo is of the male sex is strongly supported by the Schedule returns, in which it is shown (Tables VIII and IX) that prolonged gestation is clearly associated with a greatly increased proportion of male pups born. The size of the litter has apparently nothing to do with the length of gestation.

The tendency of individual male or female parents to produce a marked proportion of offspring of one sex, is examined (Table X). It is seen that bitches which are concerned in the production of four or more litters show a much higher percentage of variability than sires, but that the sire may exert influence is clear from the Mastiff records.

Details supplied by Basset hound and Dachshund Schedules give some support to the popular belief that seasons affect the proportion of males and females born; the figures available, however, are far too small to allow of a trustworthy test being made.

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The Natural Units of Mass, Length and Time. By H. C. POCKLINGTON, M.A., St John's College.

[*Read* 11 March 1907.]

1. The units in terms of which physical quantities are usually expressed, those of the C.G.S. system, form a group the members of which are derived in a natural manner from three fundamental units, the centimetre, the gramme and the second. But these fundamental units are, from the physical point of view, not merely arbitrary but even of arbitrary orders of magnitude. They are indeed of the same order of magnitude as the smallest lengths, masses and times that are directly appreciable by the senses. We might choose as natural units of mass and length the mass of a hydrogen atom and its radius, but unfortunately these are not known with any accuracy, and moreover there is nothing to give us a corresponding unit of time. We prefer for the sake of uniformity to adopt an indirect method in each case.

2. Our method for discovering the natural fundamental units is based on the hypotheses that all the properties of matter depend ultimately on the properties of some ether, and that this ether has a high degree of simplicity. A knowledge of the properties of this ether would (disregarding the difficulties of the mathematical analysis necessary) lead to a knowledge of the possible kinds of matter and their properties. The value of any given property (e.g. the tensile strength of a substance) would be given by an expression containing the numbers representing the various fundamental properties of the ether, raised to certain powers, and a numerical coefficient. The latter will never be very large or very small; in the case of the simpler properties we may expect it to lie between 10 and $\frac{1}{10}$, while in more complicated properties, such as second-order effects, we may expect a wider range. This theorem, which is of fundamental importance for our purpose, cannot be proved by rigorous methods, but one can convince oneself of its truth by examining a list of the formulae deduced from the assumptions of any theory.

3. We can in general by choosing our fundamental units of mass, length and time make the numerical values of any three quantities equal to unity. If the ether has only three fundamental qualities we can make the numerical values of the quantities defining them equal to unity, and the value of any quantity defining a property of matter will then reduce to the above-mentioned numerical coefficient, and so cannot differ greatly

from unity. If the ether has more than three fundamental qualities, we cannot do as suggested above, but we can reduce the various constants to numbers that are either moderate or moderate multiples of powers and products of the new values of the outstanding qualities of the ether. The method can in any case only give the orders of magnitude of the units, but as will be seen, the admissible range of value is not great, less indeed than that of the earlier determinations of the atomic dimensions.

4. The physical constants with which we have to deal are of two kinds, constants of nature and constants of particular substances. In the latter case we must have some method for obtaining a particular value from the many values for the various substances. We may reasonably say that hydrogen is marked out among the elements by being the first of the series, and that the formulae connected with that element must be the simplest, and hence that we should choose the constants connected with hydrogen. In many cases, however, this cannot be done, the constant in question not having been determined for hydrogen, and in any case we may doubt whether hydrogen is so pre-eminently fitted for our purpose that we may disregard the other elements. We therefore follow another plan. If a given constant appears to lie between two values, the geometric mean of these is taken; if the range is from a finite number to either zero or infinity, the finite number is taken; if the range is from zero to infinity, we cannot take any number to be a constant of nature. We first discuss properties that do not involve electrodynamics.

5. The elements differ greatly in density, those of higher atomic weight having in general a greater density. The "atomic volume" is more nearly constant. Now the graph of this quantity shows several minima of approximately the same value, while the maxima* differ considerably. We hence take the geometrical mean of these minima, 3·6, 10·5, 6·6, 8·3, 8·4, which is 7·0 cm.^{3}/gm.

The heat of combustion varies considerably, but reasons are given in Watts' *Dictionary of Chemistry*, vol. VII. p. 614 (1883) which lead one to consider 18000 cal./gm. as a constant of nature. In C.G.S. units this is $7{\cdot}6 \times 10^{11}$ cm.^{2}/sec.^{2}

The latent heat has no definite minimum. Its maximum value is found in the case of steam, and is 536 cal./gm. or $2{\cdot}3 \times 10^{10}$ cm.^{2}/sec.^{2}

The absolute critical point of a substance divided by its molecular weight is fairly constant, and hence the velocity of

* In the graph as usually drawn these appear to be chance points on asymptotic branches. If we plot the reciprocal of the atomic volume, especially if we plot it against the position of the element in the series of elements instead of the atomic weight (whereby we get a smoother curve), we see that they are really maxima.

the molecule in this state is roughly constant. Excluding hydrogen and water, it varies from $3{\cdot}3 \times 10^4$ for nitrogen to $7{\cdot}6 \times 10^4$ for ammonia. The square of the geometrical mean is $2{\cdot}5 \times 10^9$ cm.^{2}/sec.^{2} The geometrical mean of the selected values of quantities measured in cm.^{2}/sec.^{2} is $3{\cdot}5 \times 10^{10}$ cm.^{2}/sec.^{2}

According to Quincke* the surface tension of liquids divided by their density ranges between 22 and 88, with only a few exceptions. The geometrical mean is 44 cm.^{3}/sec.^{2}

The tensile strength of materials has no lower limit. Its higher limit is found in steel and is $1{\cdot}4 \times 10^{10}$ dynes per sq. cm. Critical pressures vary from 2×10^7 for hydrogen to $1{\cdot}9 \times 10^8$ for water. Young's modulus and the modulus for volume elasticity of liquids have much higher limits, 2×10^{12} and 3×10^{11}. Probably in order to obtain the physical constant that we require we should replace the length or volume that occurs in the numerator of the expression for the modulus by the sum of the intermolecular lengths or by the co-volume; these last-named quantities being unknown, we cannot make use of the coefficients of elasticity. The mean of the values retained is $3{\cdot}7 \times 10^8$ gm./cm. sec.^{2}

The coefficient of viscosity has no greater limit, its lower limit is found in ether, ·003 gm./cm. sec., if we disregard the case of liquefied carbon dioxide, which appears to be exceptional.

6. Let us now choose l, m, t as new units of length, mass and time. The centimetre will now be $1/l$ units of length, and similarly for the others. To find the values of the various quantities in the new units we have only to write $1/l$, $1/m$, $1/t$ for cm., gm., sec. Equating the new values to unity we have

$$l^3/m = 7,$$
$$l^2/t^2 = 3{\cdot}5 \times 10^{10},$$
$$l^3/t^2 = 44,$$
$$m/lt^2 = 3{\cdot}7 \times 10^8,$$
$$m/lt = 3 \times 10^{-3}.$$

These equations are not consistent. Solving them by the method of least squares on the assumption that equal proportional errors of the right-hand sides are equally probable, we have,

$$l = 4{\cdot}0 \times 10^{-8}, \quad m = 1{\cdot}4 \times 10^{-23}, \quad t = 5{\cdot}5 \times 10^{-13}.$$

The values of the quantities in question in terms of the new units are 1·5, 6·6, ·21, ·33, 4·7.

The fact that these numbers are all near to unity tends to confirm our original hypothesis. We may note that the weight of an atom of hydrogen as deduced† from experiments on the

* *Smithsonian Physical Tables*, p. 129 (1896).
† J. J. Thomson, *Conduction of Electricity through Gases*, p. 130.

discharge of electricity through gases is $1{\cdot}1 \times 10^{-24}$ gm., or $\cdot 07\ m$. There are two other elements marked out by characteristic properties, iron and radium. The geometric mean of the weights of the atoms of these three is $2{\cdot}6 \times 10^{-23}$ gm. $= 1{\cdot}8\ m$.

7. The velocity of light is 3×10^{10} cm./sec. $= 4{\cdot}2 \times 10^5\ l/t$, a value which certainly is not small, and cannot be made small by any change in the units, for we already have had velocities such as 5×10^4 and $8{\cdot}7 \times 10^5$. We thus have clear evidence of the existence of a fourth fundamental quality of the ether. We shall denote the value of the velocity of light in the new units by v. If there is no fifth fundamental quality all quantities should in the new units reduce to multiples of some power of v by numbers that are neither large nor small.

The electric charge associated with a gramme-equivalent of an element in electrolysis is an important constant of nature. Its value is $2{\cdot}9 \times 10^{14}$ electrostatic* units of charge per gramme or $75\ \sqrt{(l^3/mt^2)}$.

The still more important quantity, the charge on an electron, is unfortunately not known with accuracy. Assuming as above that the atom of hydrogen weighs $1{\cdot}1 \times 10^{-24}$ gm., we find it to be $3{\cdot}2 \times 10^{-10}$ C.G.S. $= 5{\cdot}9\ \sqrt{(ml^3/t^2)}$.

We shall require to know the new fundamental unit of temperature. This may be defined in various ways. Since the atomic heats of all elements are nearly the same, we may define the unit as the rise of temperature produced by adding one unit of energy in the form of heat to m gramme-atoms of the element. This gives the value 19° C. Another value, 21° C., is got from the moderately constant ratio of the absolute critical point of a substance to its density relative to hydrogen. The lowest known melting point is of the same order of magnitude. Again if we define unit temperature as that at which the kinetic energy associated with each degree of freedom of the molecule of a gas is unity when expressed in the new units, we obtain 1600°. The highest temperature at which a solid can exist is perhaps about 3000°. The mean of these is 210° absolute, or − 63° C. In the case of quantities that vary with the temperature we should take the values that they have at this standard temperature; it is near enough to take their values at 0° C.

The minimum electromotive force that will cause a spark through air is about 320 volts $= 1{\cdot}1$ C.G.S. $= 810\ \sqrt{(lm/t^2)}$. This number is not small, neither is it of the same order of magnitude as v.

The dielectric strength of insulating liquids is about 200 C.G.S.

* It is immaterial for our purpose whether we use electrostatic or electromagnetic units, as the resulting numbers will differ only in the ratio of some powers of v. For the sake of uniformity, electrostatic units are generally used.

units per cm., or $5{\cdot}9 \times 10^{-3} \sqrt{(m/lt^2)}$. We can make the same remark as in the last case.

The conductivity for heat of the true metals ranges from ·08 for lead to 1 for copper, the mean being ·28. In the new units it is 757.

The specific resistance of the true metals at 0° C. ranges from $1{\cdot}5 \times 10^{-6}$ for silver to 9×10^{-6} for platinum, the mean being $3{\cdot}6 \times 10^{-6}$ ohm cms. $= 4 \times 10^{-18}$ C.G.S. $= 7{\cdot}3 \times 10^{-6}\, t$.

The intensity of light required to halve the resistance of selenium is about equal to that of direct sunlight, i.e. ·04 cal. per sec. per sq. cm. $= 1{\cdot}7 \times 10^{6}$ ergs/cm.^{2} sec. $= 2{\cdot}0 \times 10^{-8}\, m/t^3$.

The wave-length of light that is capable of producing chemical action has a higher limit at $5{\cdot}9 \times 10^{-5}$ cms. $= 1{\cdot}5 \times 10^{3}\, l$.

The rotation of the plane of polarization of light on normal reflection from the pole of an electromagnet is from ·019 to ·013 (mean ·016) minutes of arc per C.G.S. electromagnetic unit of magnetization or $4{\cdot}8 \times 10^{-6}$ if we use radians. In the new units (electromagnetic) this is $\cdot 16t \sqrt{(l/m)}$.

The rotation of the plane of polarization of light passing through a transparent body placed in a magnetic field is directly proportional to the difference in magnetic potentials at the ends of its path and inversely to the square of the wave-length. The constant which is obtained by multiplying Verdet's constant by the square of the wave-length has dimensions of length divided by magnetic force. Its value in electromagnetic C.G.S. units when the angle is measured in radians is a maximum for lead borate, being $6{\cdot}0 \times 10^{-14} = 5{\cdot}2 \times 10^{-2} t \sqrt{(l^3/m)}$.

The ratio of the maximum elongation of iron produced by magnetizing it to the original length is $1/720000 = 1{\cdot}4 \times 10^{-6}$. Being a mere number it has the same value in the new units.

The susceptibility of diamagnetic substances has its maximum value in bismuth, $2{\cdot}5 \times 10^{-6}$ C.G.S. electromagnetic units. Since this is a mere number, it will have the same value in the new units.

In the case of ferromagnetic substances there is no definite susceptibility. The maximum magnetization is found in iron and is 1700 electromagnetic C.G.S. $= 5{\cdot}0 \times 10^{-2} \sqrt{(m/lt^2)}$ electromagnetic units.

The magnetic force required to half-saturate iron is about 5 C.G.S. which is $1{\cdot}5 \times 10^{-4} \sqrt{(m/lt^2)}$ in our units.

The rotation per centimetre of polarised light passing through an optically active substance is roughly proportional to the reciprocal of the square of the wave-length. The constant involved is the rotation per cm. multiplied by the square of the wave-length. The maximum is found in cinnabar and is $1{\cdot}9 \times 10^{-10}$ cms. or $4{\cdot}8 \times 10^{-3} l$.

The thermoelectric phenomena are given by the points where the lines of the thermoelectric diagram cut the axis of temperatures and their slope. The first quantities are not very small. The slope has its maximum value for nickel, ·24 microvolts per degree per degree or, in the new units, $2{\cdot}6 \times 10^{-2}$.

8. The diagram represents these numbers on a logarithmic scale, numbers greater than unity being represented by marks above the line, while those less than unity have their reciprocals represented by marks below the line. As anticipated, the numbers

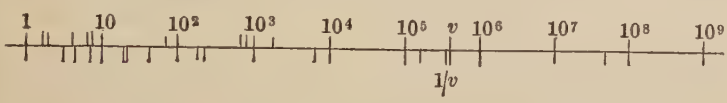

Fig. 1.

crowd together in the neighbourhood of unity, but the range is much greater than one would expect. This is not to be ascribed to the complexity of the phenomena causing large coefficients to enter into the equations expressing the quantities in terms of the fundamental properties of the ether, for the velocity of light, which can hardly be a complicated function of these properties, has the large value $4{\cdot}2 \times 10^5$. If this velocity be a fourth fundamental property, we should expect a crowding of the points about this value, which we do not find. This, however, depends on the kind of unit used to measure electromagnetic quantities in. If we had measured them in electromagnetic units we should have had several cases of approximation to some power of v. We may possibly explain the large values of some of the quantities by supposing that they contain $\sqrt{v}$. There is no indication of any fifth fundamental quality of the ether.

9. We may now take those quantities that lie between 100 and $\frac{1}{100}$ and find what units will reduce them to small values. I find in this way the units

$$l = 7{\cdot}60 \times 10^{-8} \text{ cms.}, \quad m = 2{\cdot}34 \times 10^{-23} \text{ gms.}, \quad t = 7{\cdot}50 \times 10^{-13} \text{ sec.}$$

These are very near the old units, and if we express the quantities anew in terms of these units none of the conclusions reached above will be altered. We may note however that the values for the mean mass of the atom and the charge on the electron are now 1·08 and 2·4 respectively, values which are practically unity.

As both these quantities are of fundamental importance, it is highly confirmatory of the present theory that their new values should be near to unity.

Another quantity of fundamental importance is the constant of gravitation, $6{\cdot}6 \times 10^{-8}$ or $2{\cdot}0 \times 10^{-23}$ in the units of § 9. As v

in these units is $3{\cdot}0 \times 10^5$, the constant is $1{\cdot}3v^{-6}$, and again we have a number, 1·3, which is near to unity.

10. General conclusion. There are four fundamental qualities of the ether, hence no theory of the ether and matter can explain all the facts unless it involves four such qualities. The granular theory of Reynolds* is as far as I know the only one that satisfies this condition. (The four qualities may be represented by the radius of a grain, its mean velocity, its mass, and the pressure in the medium at infinity, or we may of course choose our four quantities in other ways.) We can in four ways choose our units of length, mass and time so as to reduce three out of four of the numbers expressing these qualities to unity. One such set of units has been found in § 9.

* Osborne Reynolds, *Papers on Mechanical and Physical Subjects*, Vol. III. 'The Submechanics of the Universe.'

Some New Platinocyanides. By L. A. Levy, Clare College. (Communicated by Dr Fenton.)

[*Read* 11 March 1907.]

In the course of an investigation of the properties of platinocyanides—more particularly with respect to their fluorescence—it has been necessary to prepare salts of bases whose constitution renders the gradual substitution of hydrogen by alkyl and other groups possible. By this means the effect of various atomic groupings can be estimated. To this end the platinocyanides of hydrazine and hydroxylamine were prepared and, as their properties proved interesting, they were described in a paper published in the *Journal of the Chemical Society*, Jan. 1906. In continuation of this work, the following salts have been prepared:

Guanidine Platinocyanide.

Guanidine (a base whose hydrogen atoms are readily substituted) platinocyanide was prepared by double decomposition between the calculated quantities of guanidine carbonate and barium platinocyanide. After filtering off the precipitated barium carbonate and evaporating in a desiccator, long silky white needles, which are very soluble in water, are obtained.

0·0569 of salt on ignition gave 0·0265 of platinum.

Pt = 46·57 °/₀.

Pt calculated for $(CN_3H_5)_2H_2Pt(CN)_4$ = 46·54 °/₀.

The white crystals are therefore probably anhydrous.

The salt does not appear to present any points of interest.

'Nitron' Platinocyanide.

Nitrogenous bases such as hydrazine and hydroxylamine yield interesting platinocyanides. The 'nitron' (diphenylendoanilodihydrotriazole $C_{20}H_{16}N_4$) salt was prepared to see if it exhibited any interesting properties. It was prepared by adding, to an acetic acid solution of nitron, the calculated quantity of hydroplatinocyanic acid in aqueous solution. A buff-coloured amorphous precipitate, insoluble in water, was immediately produced. This was washed free from acetic acid, dried and dissolved in absolute alcohol. Shining grey lamellar crystals were deposited.

0·1612 of the salt on ignition gave 0·0350 of Pt.

Pt = 21·7 °/₀.

Pt calculated for $(C_{20}H_{16}N_4)_2Pt(CN)_4$ = 21·1.

A difference in weight of one milligram corresponds to 1·3 °/₀ Pt, and hence great accuracy is not to be expected. The substance does not exhibit any interesting properties.

Uranyl Platinocyanide.

Most uranyl salts and most platinocyanides are fluorescent. Uranium compounds, being radio-active, emit radiations which are capable of making platinocyanides fluoresce. Uranyl platinocyanide should therefore prove interesting for a double reason.

The salt was prepared by double decomposition between the calculated quantities of uranyl sulphate and barium platinocyanide. After filtering off the precipitated barium sulphate, a green solution remained which gave the reactions for uranyl and platinocyanide ions. On allowing this solution to evaporate in a desiccator at ordinary temperatures, red crystals with strong green metallic reflexion are obtained. If the solution is evaporated on a water bath imperfect crystals of a yellow colour are left. This yellow form, when cooled, passes into the red-green form. These two forms may therefore be enantiotropic modifications of the same substance or they may be differently hydrated forms. In view of the great tendency of many platinocyanides to form several brightly-coloured hydrates (cf. magnesium, hydroxylamine and hydrazine salts), the latter explanation is probably the correct one.

The red-green modification is transformed into the yellow form at a temperature of 39° C. On passing a current of dry CO_2 over the powdered red-green modification the colour changes to greyish-black and no further change takes place. The loss of weight is very small. This grey powder still turns yellow on warming. I intend the further investigation of this salt and hope to publish the results in a subsequent communication.

A study of the Navicular in the Human and Anthropoid Foot. By T. Manners-Smith, M.B., Downing College. (Preliminary note.) (Communicated by Professor Macalister.)

[*Read* 25 February 1907.]

Of the bones of the human foot the navicular is perhaps the most interesting. For this there are various reasons, morphological, mechanical or both.

The Os Naviculare.

Facies articularis posterior or Astragalar Surface. The whole of this surface is occupied by the caput tali and, as a rule, the caput is confined to this area. In some cases, however, the caput also articulates with the tuberosity (see below).

The shape of the Facet. The facet for the caput tali is generally referred to in English text-books as a large oval, concave facet. Phitzner figures two types of surface, a quadrilateral and an egg-shaped, corresponding to the two types of ground plan of the navicular, which he describes, i.e. a cuboidal and an egg-shaped.

In none of the specimens examined by me is the astragalar facet a perfect oval. It approaches the oval, however, in 33. It is egg-shaped in 85. In most cases however (434) it is pear-shaped. In the last two varieties the narrow end of the egg or pear is directed towards the tuberosity. Sometimes (10) it is almost quadrilateral, occasionally (4), triangular. In the remaining cases it was too much damaged to ascertain its exact shape.

According to Phitzner, the difference in the ground form of the navicular, and consequently the difference in the shape of the surface for the caput tali, depends upon the absence or presence of the lateral plantar process or plantar point; in the first case, we have the egg-shaped, in the second, the cuboidal ground plan.

He states that the projection of this part of the bone must at once arouse the suspicion that we are dealing with an inconstant, originally independent part of the skeleton, and that this portion of the navicular, in reality, is formed by the assimilation of an inconstant tarsal, namely, what he calls Cuboides secundarium. If this be so, however, we should expect the process to remain separate in some cases. In none of the specimens which I examined did I find the plantar point existing as a separate ossicle, but in one I found a trace of a suture on the facies articularis posterior and facies lateralis articularis anterior (cubo navicular articulation). The facet for the cuboid was subdivided

by a groove into two facets, the groove was continuous with the suture on the astragalar surface.

The large size of this process however in the cuboidal type of bone can be explained equally well mechanically as morphologically. It must be remembered in dealing with this bone, that it is later in its ossification than any of the other tarsal bones and that the child is walking, from, say the second to the fifth year, with its navicular in a cartilaginous condition. During this period, the inferior calcaneo navicular ligament is exerting traction on the plantar point, and in this way, supposing the bone ossifies late, and the child is particularly active, the point might easily be drawn out into a prominent process. Its nipple-like appearance in many cases certainly suggests this mode of origin.

The plantar point is well developed in most cases; very small in some of the specimens, and in a few absent. There are two types of plantar point, (*a*) the spur-like or nipple-like, (*b*) the rounded. It is spur-like or nipple-like in 318 specimens and rounded in 134. It appears to be better developed in these ancient bones than in modern specimens.

The nature and depth of the concavity. This varies considerably in different specimens. In a few cases it is almost absent, the facies articularis posterior being nearly flat. There are two types of concavity.

(*a*) That with an increase of the concavity in the long diameter, which depends upon the extent of projection backwards of the upper and outer part of margo dorsalis posterior (the margin of the broad end of the pear-shaped facet for caput tali), since the tibio plantar angle (narrow end of the pear) projects backwards considerably in nearly all cases.

(*b*) That with an increase of the concavity in the shorter diameter, which in turn depends upon the projection towards the posterior surface of the plantar point.

When the concavity was especially deep, the increase in most cases (238) was in the longer diameter only, in the shorter diameter only in 55, in both diameters in 82. It is interesting to compare the type of concavity in man with that existing in the Simiidae. In all four genera the depth of the concavity is chiefly in the long diameter and the plantar point does not extend towards the facies articularis posterior, but is small and is confined to the facies plantaris. Since movement at the astragalo navicular joint in the Simiidae is especially free, the view is rather suggested that a deeply concave surface for caput tali, in the long diameter in man, is also correlated with great freedom of movement in a lateral direction at the same joint, so that dislocation may be prevented during the side to side movement. The depth of concavity in the shorter diameter only, in man,

as in the above 55 cases, since it is dependent chiefly on the projection of the plantar point and is not found in the Simiidae, is possibly correlated with a high and stable tarsal arch.

Anterior Surface. Facies articularis anterior.

Articulatio Cuneo Navicularis I.

The facet for internal cuneiform. There are two chief types of surface; in the majority (393), the dorsal and plantar borders are on the same level, or the dorsal border is only slightly more projecting than the plantar. In 187 specimens there is a shelving away of this surface towards the plantar aspect of the foot and in the direction of the tuberosity. In addition, the internal cuneiform facet has often (170) a very slight vertical or oblique ridge, or eminence, about its middle. In some cases the ridge or eminence is so strongly developed as to subdivide this surface into two almost equal parts. This ridge probably marks the junction of two components, dorsal and plantar, of the internal cuneiform which may, in some cases, remain separate. Phitzner found two surfaces on the navicular at this joint in ten specimens. In those cases, where the above eminence is especially well developed, and accompanied by the above-mentioned shelving away of the surface, the internal cuneiform facet is directed very obliquely, its surface looking somewhat downwards. This will have a tendency to throw the internal cuneiform and through it the big toe plantarwards. This is probably correlated with greater freedom of flexion of the hallux which would be expected in a non-boot wearing people.

Articulatio Cuneo Navicularis II.

The facet for the middle cuneiform. This is also wedge-shaped in most cases, in one triangular; the apex points towards the plantar surface.

Articulatio Cuneo Navicularis III.

The facet for the external cuneiform. In most cases (239) this facet has the shape of a very blunt wedge with the narrow end of the wedge pointing towards the cuboidal facet; in 59 cases it points towards the plantar surface.

In 189 cases this facet is four-sided, in two pentagonal, with rounded angles, near the cuboidal facet, in both varieties. This surface is either flattened or concave. It was slightly concave and four-sided in 53 specimens. In a few, markedly concave.

When the concavity is well marked and this facet is four-sided we have the anthropoid type of articular surface in this situation. It is especially well marked in the gorilla, but is present in all the Simiidae.

Facies lateralis. Articulatio cubo navicularis. The cuboid facet is situated at the junction of the facies articularis anterior, and facies lateralis. It is present in 332 specimens or about 70 per cent. of those examined with reference to this articulation.

Articulatio calcaneo navicularis. This occasional facet for the os calcis is present in 13 specimens, 8 right and 5 left. The facet is close to the surface for caput tali, between the cuboidal facet and the plantar point. Its shape varies slightly, in two cases it was rhomboidal, in one triangular, in one oblong, in one wedge-shaped, in three cases there was a fairly sharp ridge separating it from the cuboidal facet. Phitzner found this articulation in 8 specimens. The presence of this articulation is due according to Phitzner to the existence of a rudimentary calcaneus secundarius which has fused with the os calcis.

Tuberositas ossis navicularis.

This may be considered, from a descriptive point of view, under size, prominence and shape, and from a morphological, embracing the embryology of the tuberosity, its components and their nature.

Description: In the following account I have included as tuberosity that portion of the whole navicular which projects mesially and plantarwards, beyond a line drawn round the bone from the tibio plantar angle (apex of pear-shaped facet for caput tali) to the apex of the facet for the internal cuneiform.

The apex of the tuberosity may occupy three situations:

(*a*) It may be situated at a small tubercle close to and dorsal of the tibio plantar angle (apex of pear-shaped astragalar facet). This may be called the apophysial apex.

(*b*) It may be situated a line or two distally and plantarwards of the above tubercle. This may be called the epiphysial apex.

(*c*) It may be produced proximally, so as to occupy a position $\frac{1}{8}$ to $\frac{1}{4}$ of an inch posterior to the above tubercle. This may be called the sesamoid apex.

Morphology. The portion of bone included in the above description as tuberosity will be found to consist of a variable number of elements of different morphological value. The evidence derived from those abnormal cases in which a separate ossicle is formed in this situation would suggest that the whole tuberosity is made up of one, two, or in some cases, three components.

(*a*) A portion near the corpus which is merely an apophysis of that body, from this the whole of the facies anterior and facies dorsalis and facies articularis are formed, together with a little

tubercle at the upper part of the latter surface and close to the tibio plantar angle (apex of the pear-shaped facet for caput tali).

(*b*) The epiphysial portion. The part formed from the epiphysis is either prismatic or oval in shape, the exact shape depending on the presence or absence of a third element of the tuberosity.

(*c*) The last and most variable element of the tuberosity is the so-called sesamoid bone in the tendon of the tibialis posticus which may fuse with the tuberosity. When it is present it produces the tuberosity proximally, is somewhat pea-like in shape resembling closely the human pisiform bone. It is the presence of this element which gives rise to the elongated type of tuberosity; with its absence we have the prismatic type. When this element is present there is not infrequently an extension of the surface for caput tali on to the tuberosity (facies articularis tuberositatis).

The single bone which Phitzner describes as tibiale externum corresponds in shape and position to the parts described above under (*b*) and (*c*). It is true that we only get a single separate ossicle in this position. In one of my specimens however the ossicle was imperfectly bipartite and Phitzner mentions five cases in which it was in the same condition. This would suggest the view that the single ossicle may consist of both of the above-mentioned elements (*b*) and (*c*) fused. It may be conjectured from the shape of the articular surfaces, or from those of coalescence, which element is missing.

Although therefore as Phitzner maintained, the sesamoid bone in the tibialis posticus (tibiale externum, Phitzner) may fuse and form part of the tuberosity, it probably only forms the proximal portion of the tuberosity, and the occasional bipartite condition of the ossicle found here together with the shape of the surfaces of articulation or coalescence would suggest that there is another element between this sesamoid element and the apophysial part of the tuberosity, viz. that which I have described as the epiphysial portion. Bardeleben has shown that there is a separate cartilage at the tuberosity up to the second month of foetal life. Phitzner, however, apparently would claim this cartilage as the same element as his tibiale externum. The matter can only be cleared up by the examination of a large number of young tarsal bones varying in age, preferably from the fifth to the twenty-fifth year.

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A Series of Substituted Bromanilines. By J. R. Hill, B.A., St John's College. (Communicated by Mr H. O. Jones.)

[*Read* 11 March 1907.]

The preparation of these compounds was undertaken with the object of obtaining from them by the addition of benzyl or allyl iodide two series of substituted ammonium compounds containing an asymmetric nitrogen atom. All the members of such a series would contain a bromine atom in the phenyl group, and would in this respect differ from the asymmetric nitrogen compounds described by Miss M. B. Thomas and Mr H. O. Jones (*J. C. S.* 1906, p. 280). The difference in rotatory power caused by the introduction of the bromine atom could then be examined. In this way the change in the optical activity produced by the increase in weight of the phenyl group could be studied. This work is at present in progress.

The tertiary bromanilines described in this paper were prepared by the bromination of the corresponding tertiary anilines. The latter were obtained from methyl aniline as described in the paper referred to above. The methyl aniline was heated with the various alkyl bromides on a water bath, producing more or less readily the hydrobromide of the di-substituted aniline. The free base was then liberated with potash and purified by distillation.

The tertiary base thus obtained was next brominated. The method of bromination used was that employed by Karl Fries for brominating amines (*J. C. S. Ab.* 1906, p. 644). The base was dissolved in acetic acid and a solution of bromine in acetic acid slowly run in, keeping the liquid cool by immersion in water. One molecule of bromine was used for one molecule of the base. In this way the hydrobromide of the bromaniline was obtained in acetic acid solution.

In the first case tried—that of methyl*iso*propylbromaniline—the hydrobromide was obtained in crystalline form. In all the other cases the hydrobromides remained as gums: the *iso*butyl and *iso*amyl compounds showed signs of crystallising after standing several weeks.

The bromanilines, liberated by the addition of potash to solutions of the hydrobromides, were oils with one exception, namely methyl*iso*propylbromaniline. This on recrystallisation from alcohol was obtained in beautiful lustrous plates. Five of these bromanilines were prepared. Of the two substituting groups one was, of course, methyl in each case; the other was ethyl, propyl, *iso*propyl, *iso*butyl or *iso*amyl. The liquid bromanilines were purified by fractional distillation *in vacuo*.

These compounds had now to be characterised. Some diffi-

culty was experienced in obtaining suitable derivatives for this purpose. A crystalline hydrobromide could only be readily obtained in the one case mentioned above. All the bases, however, gave crystalline compounds more or less readily with methyl iodide. The melting points of these quaternary ammonium iodides were taken, but they all lay within a comparatively small range of temperature.

An attempt was made to obtain the platinichlorides, but without success.

The picrates were found to be readily obtainable. Alcoholic solutions of the base and of picric acid were mixed, and, on allowing them to evaporate, the picrates separated. They crystallised well from alcohol. Here again the melting points were in some cases very close together. All the bases readily formed crystalline compounds with allyl and benzyl iodide, giving rise to the two series of asymmetric nitrogen compounds which are the final object of the research.

The next problem, and one which proved to be of considerable difficulty, was the fixing of the position of the bromine atom. This was first attempted by the action of potash on the methyl iodide addition compounds. It was thought that dimethyl bromaniline would result, which could be identified as ortho, meta or para. But there was no action, even with the strongest potash.

Silver oxide was next tried with the same compounds in alcoholic solution. It reacted readily and gave a strongly alkaline solution of the quaternary hydroxide. This was evaporated down on the water bath and then distilled. According to Hofmann the group of highest molecular weight should split off when a quaternary hydroxide is heated. It was consequently expected that dimethyl bromaniline would be the final product in each case. This result was unfortunately only realised in one case—that of methylethyl bromaniline. The quaternary hydroxide obtained from this compound gave dimethyl-para-bromaniline. Thus the bromine is in the para position in the case of methylethylbromaniline.

All the other quaternary hydroxides, on decomposition, split off a methyl group instead of the higher group, and thus gave back the original bromaniline. They could not therefore be orientated in this way. Another method was consequently looked for.

Lauth (*Ber.* 6, p. 677), by passing dry hydrochloric acid gas over dimethyl aniline at 180° C., split off the methyl groups and obtained aniline. This method was tried with dimethyl bromaniline. Methyl chloride was evolved, but the resulting product was an uncrystallisable mixture and the method was abandoned.

The only other method of orientation that suggested itself was to start with methyl p-bromaniline and try to form the di-substituted p-bromanilines from it. If they were found to be identical

with those described in this paper, then the position of the bromine atom would be established. This is rather a long process and has not yet been completed.

Methylethylbromaniline.

This compound has been obtained by Claus and Howitz (*Ber.* 17, p. 1327); but they did not prepare any derivatives.

It was prepared by the bromination of methylethylaniline in acetic acid solution as described above. After liberating with potash it was fractionally distilled under reduced pressure. Its boiling point is 149°—152° C. at 13 mms.

With methyl iodide it readily gave a quaternary iodide; this was recrystallised from alcohol, in which it was only slightly soluble. Melting point 189° C.

The picrate first came down as an oil, which afterwards crystallised. It was recrystallised several times from alcohol and water. Melting point 138° C.

The base also gave crystalline compounds with allyl and benzyl iodide. The melting point of the allyl iodide compound was 134° C.

The methyl iodide compound was heated with silver oxide and alcohol on the water bath. The solution of hydroxide was filtered and evaporated down. It was then distilled, undergoing decomposition. The oil which collected in the receiver crystallised on standing and, after repeated recrystallisations from alcohol, melted at 52°—53° C. When mixed with dimethyl p-bromaniline its melting point was not lowered.

With methyl iodide it gave a quaternary iodide, melting at 200° C., identical with the compound which dimethyl p-bromaniline forms with methyl iodide. It is thus evident that this decomposition product of the hydroxide is dimethyl p-bromaniline. Consequently the bromine atom in methylethylbromaniline is in the para position.

Methylisopropylbromaniline.

This was the first compound of the series to be prepared. Methyl*iso*propylaniline was first prepared from methylaniline and *iso*propyl bromide. This was then brominated, giving the hydrobromide of methyl*iso*propylbromaniline, which crystallised out on evaporating down the acetic acid solution. The hydrobromide was more readily obtained by liberating the free base from the acetic acid solution, dissolving it in aqueous hydrobromic acid and crystallising out.

The hydrobromide could be crystallised from either alcohol or water. It melted at 69° C.

The pure hydrobromide was then decomposed with potash and the free base came down as an oil which solidified on cooling. It was recrystallised from alcohol several times, giving beautiful crystals melting at 34° C.

Analysis of this base gave the following results:

0·2075 gram gave 0·4025 gram CO_2, 0·1154 gram H_2O.
C = 52·89, H = 6·18.
$C_{10}H_{14}BrN$ requires C = 52·64, H = 6·14 per cent.

On mixing with methyl iodide the quaternary iodide slowly came down. This was recrystallised from alcohol, in which it was fairly soluble. Melting point 167° C.

The picrate was readily obtained and recrystallised from alcohol. Melting point 138° C.

The base also gave crystalline compounds with allyl and benzyl iodide. The allyl iodide melted at 150° C., and on analysis gave the following results:

0·2142 gave 0·3075 CO_2, 0·0978 H_2O. C = 39·15, H = 5·07.
$C_{13}H_{19}BrNI$ requires C = 39·39, H = 4·8.

The quaternary hydroxide, obtained from the methyl iodide compound, on decomposition gave crystals melting at 34° C. These were identified as methyl*iso*propylbromaniline by means of the picrate and methyl iodide compound.

Methyl-n-propylbromaniline.

It was prepared in a similar way to the others by the bromination of methyl-n-propylaniline. It boiled at 149°—152° C. at 5 mms.

The methyl iodide compound comes down rather slowly and is readily soluble in alcohol, from which solution good crystals are deposited. It melts at 167° C.

The picrate is readily formed and, after recrystallising several times from alcohol, melted at 126° C.

The methyl iodide compound gave a quaternary hydroxide, which on decomposition gave back the original base.

Methylisobutylbromaniline.

Prepared by the bromination of methyl*iso*butylaniline. It distilled over between 169° and 173° C. at 9 mms.

The quaternary iodide came down rather slowly on adding methyl iodide to the base. After repeated crystallisations from alcohol it melted at 167°—168° C.

The picrate was formed with the greatest ease and crystallised

well from alcohol, in which it was only slightly soluble. It melted at 136°—137° C.

The quaternary hydroxide obtained from the methyl iodide compound, on decomposition, gave back methyl*iso*butylbromaniline.

Methylisoamylbromaniline.

It was prepared in a similar way to the others. It distilled at 165°—170° C. at 5 mms.

The quaternary iodide came down readily on adding methyl iodide and crystallised well from alcohol. Melting point 176° C.

The picrate was only obtained in crystalline form with difficulty. After recrystallising from alcohol its melting point became constant at 89° C.

The quaternary hydroxide, obtained from the methyl iodide compound, decomposed on heating to give back methyl*iso*amylbromaniline.

It will thus be seen that all these quaternary hydroxides, except that of methylethylbromaniline, split off a methyl group, on heating, and give back the original base.

In conclusion, I wish to express my thanks to Mr H. O. Jones for suggesting this work and for his kind advice during the course of it.

Some observations on Complex Carbonates. By T. B. Wood, M.A., Gonville and Caius College, and H. O. Jones, M.A., Clare College.

[*Read* 11 March 1907.]

The experiments described in this paper were undertaken with the object of investigating the stability of the solutions made by Soldaini (*Gazz. Chim. Ital.* 6. 322) and Ost (*Ber. d. d. Chem. Ges.* 23. 1035), which contain copper sulphate, potassium carbonate and bicarbonate, are stable on boiling, and are used as substitutes for Fehling's solution. Gröger (*Ber. d. d. Chem. Ges.* 34. 429) had found that these solutions deposited basic copper carbonate, or a double copper potassium carbonate, or both, on standing, and, under certain conditions, had obtained a salt which gave analytical numbers agreeing with the composition

$$K_2CO_3 . 8CuO . 7CO_2 . 17H_2O.$$

Copper salts dissolve freely in concentrated solutions of potassium carbonate to give deep blue solutions very like Soldaini's solution, but these solutions give a black precipitate of hydrated copper oxide on boiling: this decomposition is prevented by the addition of bicarbonate.

Extending these observations to other metallic salts we found that the salts of cobalt, nickel, iron (ferrous and ferric), manganese, chromium, aluminium, uranium, zinc, cadmium, bismuth, calcium, silver and magnesium all dissolved in concentrated solutions of potassium carbonate and in most cases deposited definite crystalline double carbonates on standing. In the other cases, notably ferric salts, aluminium and chromium salts, no crystalline product could be obtained. Some of these salts we found had been prepared by Deville (*Ann. de Chim. et de Phys.* 80. 251) and the others by Reynolds (*Jour. Chem. Soc.* 1898, 263).

The cobalt, nickel, magnesium, manganese and ferrous salts have the general formula $K_2CO_3 . M . CO_3 . 4H_2O$, are beautifully crystalline, dissolve in potassium carbonate solution but are decomposed by water. It is remarkable that this very interesting series of salts should have received so little notice that it is not mentioned in any of the ordinary text-books.

Reynolds prepared the double copper carbonates by adding copper acetate to a concentrated potassium carbonate solution and found that three salts were deposited simultaneously: (1) blue hexagonal plates $K_2CO_3 . CuCO_3$, (2) pale blue silky needles $K_2CO_3 . CuCO_3 . H_2O$, (3) large greenish blue tables $K_2CO_3 . CuCO_3 . 4H_2O$. These salts were separated mechanically

and the conditions for the formation of an individual salt were not determined.

In order to establish the solubility relationships of copper and potassium carbonates a very large number of solubility determinations have been made. The determinations were all made at 25° C. The solutions were put in small bottles and set in a rotating shaker holding twelve bottles, which was immersed in a water-bath and kept in motion for a long time. A weighed quantity of the solution was first titrated with standard acid, the copper in the neutral solution was then estimated by adding potassium iodide and titrating the iodine liberated, or, it was estimated in a separate portion of the solution by boiling with excess of grape sugar, dissolving the precipitated cuprous oxide in ferric sulphate and titrating the ferrous salt produced with potassium permanganate. The amount of potassium carbonate present was then found by subtracting the amount of acid necessary to react with the copper carbonate from the total amount used and calculating the potassium carbonate equivalent to the acid left. At first precipitated basic copper carbonate was used as the source of copper. As long as solid potassium carbonate was present in excess, fairly consistent results were obtained in separate experiments, the results of these agree with those represented on the ascending portion of the curve from *A* to *B*.

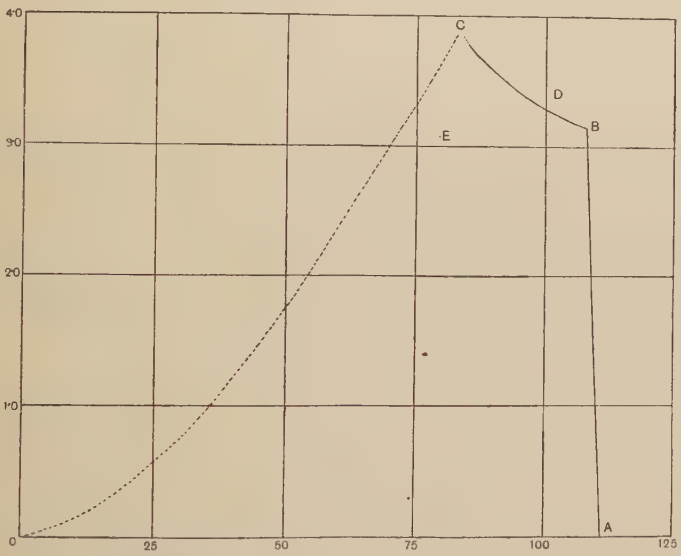
In the more dilute solutions however most erratic results were obtained, the amount of copper carbonate dissolved seemed to depend on the amount that had been added as solid. This was found to be due to the interaction of the copper hydroxide with the potassium carbonate in solution producing potassium hydrate and so altering the conditions. It was then found that solutions containing from 90 to 100 grams of potassium carbonate in 100 grams of water which had been saturated with basic copper carbonate contained about 3·5 grams of copper carbonate in the same quantity of water and deposited blue hexagonal plates of a double copper potassium carbonate on standing in the cold. This salt was found to be identical with that prepared by Reynolds. The preparation of this salt in quantity will be described later.

This double salt was afterwards used as the source of copper and the solutions were saturated in contact with the double salt.

The solutions in equilibrium with potassium carbonate as solid phase, represented by the points on the curve between *A* and *B*, had practically the same concentrations of copper carbonate now as when basic copper carbonate had been used. The point *B* at which the solution is in equilibrium with the two solid phases potassium carbonate and double salt, could be determined with fair accuracy, the solution then contains 105 grams of potassium

carbonate and 3·15 grams of copper carbonate in 100 grams of water.

The points on the curve between *B* and *C* represent solutions in equilibrium with double salt as solid phase. The results here begin to be slightly less regular and it is evident that some disturbing cause is coming into action. One cause of these irregularities is probably the existence of copper carbonate in a complex salt in solution instead of in a double salt (see later).



Ordinates, grams of $CuCO_3$ per 100 grams water.
Abscissae, ,, ,, K_2CO_3 ,, ,, ,, ,,

All attempts to fix the point at which the solution is in equilibrium with the two solid phases double salt and copper carbonate were futile, since the latter substance is not capable of existing alone and at once decomposes partially into carbon dioxide and copper hydrate. This naturally causes the formation of potassium bicarbonate in the solution and so alters the conditions. For the same reason the remainder of the curve which should represent solutions in equilibrium with copper carbonate could not be traced: if the double salt were added at the beginning, then the solution would contain amounts of bicarbonate depending on the amount of double salt added; and on the other hand if basic copper carbonate were added at the beginning, then the solution would contain varying amounts of potassium hydroxide depending on the amount of copper that had been dissolved. The presence of the bicarbonate in the first case and of potassium hydroxide in

the second was demonstrated by titration with acid, using first phenolphthalein and then methyl orange as indicators. The dotted line therefore shows the general course of the curve only and is approximately the mean between the points representing a very large number of determinations.

Sometimes when attempting to get points in the neighbourhood of the point *C* it was found that the solid at the bottom of the solution instead of being the amorphous green basic copper carbonate was the black hydrate, in these cases the solutions had been allowed to stand a very long time and their compositions which are represented by points near *D* are not on the curve.

It is clear that the conditions for the existence of the double salt are determined by the curve, it can exist in contact with solutions with compositions between those represented by the points *B* and *C*. In order to prepare large quantities of the salt a sample of basic copper carbonate was prepared and analysed, its composition was represented by $CuCO_3Cu(OH)_2\,2H_2O$. A solution of potassium carbonate containing about 100 grams in 100 grams of water was made and shaken for several days with a mixture of the basic copper carbonate, potassium carbonate and bicarbonate in the proportions required by the equation:

$$CuCO_3Cu(OH)_2\,2H_2O + 2KHCO_3 + K_2CO_3 = 2CuCO_3K_2CO_3 + 4H_2O.$$

After several days the green basic copper carbonate had been completely converted into the blue hexagonal crystals of the double salt. The double salt was then filtered from the mother liquor with the aid of the pump and was dried by pressing between layers of filter paper until the paper was no longer damped. The salt obtained in this way is identical with that obtained by Reynolds, but in some cases was found to be contaminated with potassium bicarbonate.

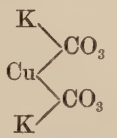
The double salt decomposes in contact with water, potassium carbonate and a very small quantity of copper carbonate going into solution and basic copper carbonate remaining insoluble. It dissolves in a solution of potassium carbonate of sufficient concentration, i.e. a solution containing more than 85 grams of potassium carbonate to 100 grams of water, to form deep blue solutions. These solutions become turbid on diluting with water, but, if not saturated with copper carbonate, do not change on boiling for some time. Solutions prepared from basic copper carbonate at once give on heating a black precipitate of hydrated copper oxide, the formation of this precipitate is prevented by the addition of potassium bicarbonate and the solutions which are stable on boiling at once give a precipitate if a little caustic potash be added to the hot solution. It is clear therefore that the

function of the bicarbonate in the solutions of Soldaini and Ost is to ensure that the copper and potassium in solution are combined with or in equilibrium with CO_3 ions and not with hydroxyl ions.

The solutions are of a very deep blue colour, slightly darker than equivalent alkaline solutions of copper tartrate and not quite so dark as equivalent solutions of copper in ammonia. The copper is precipitated from the solution by ammonium sulphide or potassium ferrocyanide but not by caustic potash in the cold; potassium iodide has no effect on the solution but potassium cyanide decolourizes it.

On electrolysis copper is deposited at both poles, this suggested the existence of complex ions in solution. To test this, experiments were made on the movement of the coloured boundary between a solution of potassium carbonate and a solution of the double copper carbonate in potassium carbonate. The blue boundary moved towards the anode on passing a current through the solution: the kathode junction remained sharp while the anode junction became diffuse. When a solution of potassium chloride was used instead of the potassium carbonate the same result was obtained, except that a slight precipitate of basic copper carbonate was formed at each junction.

It is therefore probable that the salt is to be represented as



as suggested by Reynolds and that it dissociates into the ions 2K and $Cu(CO_3)_2$. The anion $Cu(CO_3)_2$ decomposes or dissociates partially into Cu and CO_3 ions, since the solution contains enough Cu ions to reach the solubility product of copper sulphide or copper ferrocyanide on the addition of ammonium sulphide or potassium ferrocyanide respectively.

Some experiments were also made in which the solution was saturated with potassium carbonate, bicarbonate and basic copper carbonate or double salt. The phenomena were more complicated and were not fully investigated, but the solutions always contained less copper than when no potassium bicarbonate was used.

In no case did we observe the formation of the greenish blue tables of $K_2CO_3CuCO_3\,4H_2O$ described by Reynolds, but we observed the formation of the silky blue needles of $K_2CO_3CuCO_3H_2O$ during some experiments in which Gröger's salt was used as a source of copper instead of the basic carbonate or the double salt.

Gröger's salt, as stated previously, is described as

$K_2CO_3.8CuO.7CO_2.17H_2O$ or $4KHCO_3.8CuO.5CO_2.15H_2O$,

but we were never able to get analytical results which shewed that it was anything but a mixture of varying composition. A solution of potassium carbonate containing 100 grams to 100 grams of water was saturated with Gröger's salt at 25° C., the clear dark blue solution was decanted or filtered and on allowing it to stand, it set to a mass of fine needles which when filtered, dried and analysed were found to be $K_2CO_3CuCO_3H_2O$. The filtrate was found to contain 3·11 grams copper carbonate and 80 grams of potassium carbonate in 100 grams of water, and its composition is represented by the point *E* in the figure.

In studying the behaviour of other metallic salts towards concentrated potassium carbonate solutions, it was observed that cobalt salts behave in a remarkable way. When a concentrated solution of cobalt chloride is added to potassium carbonate solution a precipitate is formed, which dissolves on shaking to give an intensely reddish purple coloured solution. The solution becomes saturated with cobalt when about 4 c.c. of a saturated cobalt chloride solution have been added to 50 c.c. of a solution of potassium carbonate containing 100 grams in 100 grams of water. This solution on standing very soon begins to deposit crystals of the pink double cobalt potassium carbonate $K_2CO_3CoCO_3\,4H_2O$ prepared by Deville, after some hours the solution has lost most of its colour and eventually it becomes almost colourless. The double salt behaves very much in the same way as the corresponding salt of copper, but the solutions are more stable to heat: the original solution does not give any precipitate on heating. The solutions however undergo a change of colour on heating, becoming almost blue, but recover their original pink colour on cooling.

On electrolysing the freshly made purple solution, the coloured ion, as in the case of copper, moves towards its anode. Hence there is probably a complex ion $Co(CO_3)_2$ which is pink and negatively charged. This is of interest since in order to account for the blue colour of cobalt salt solutions under certain conditions it has been assumed that there is a blue complex ion $CoCl_4$.

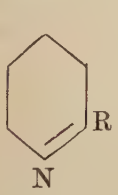
An optically active tetrahydroquinoline compound. By F. Buckney, B.A., Sidney Sussex College. (Communicated by Mr H. O. Jones.)

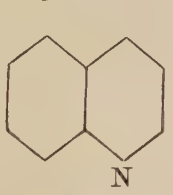
[*Read* 11 March 1907.]

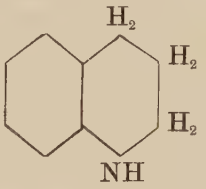
A large number of optically active compounds of quinquevalent nitrogen of the ammonium type, NR′ R″ R‴ R^{iv}, have been obtained but at the present time there is no well established case of optical activity due to a quinquevalent nitrogen atom in a cyclic nitrogen compound. The ethylene dikairolinium salts described by Wedekind (*Ber.* 1905, xxxviii. 1842) show anomalies which have as yet received no explanation. The study of these cyclic compounds becomes a matter of some importance on account of their bearing on the stereochemistry of the nitrogen atom.

Quinquevalent compounds of nitrogen derived from

picoline, from quinoline, and from tetrahydroquinoline





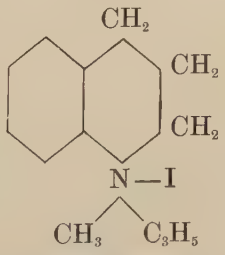


(when the two alkyl groups are different) contain no plane of symmetry and should, according to modern views, give rise to optically active isomerides.

A picolinium derivative and three tetrahydroquinolinium derivatives have been examined by H. O. Jones (*Trans. Chem. Soc.*, 1903, lxxxiii.), other tetrahydroquinoline and several quinoline compounds have been examined by the author. Up to the present only one of these compounds has been successfully resolved into the two optically active forms. In this case the two salts l-base d-acid and d-base d-acid have been isolated.

Experimental.

Allyl kairolinium iodide was prepared by mixing molecular quantities of methyl tetrahydroquinoline (kairoline) and allyl iodide in the cold. Heat was evolved and the iodide gradually crystallised out. It was pressed out on a porous plate and recrystallised from alcohol, and finally from ethyl acetate, separating as small yellow prismatic crystals melting at 130° C.



Allyl kairolinium d-bromocamphorsulphonate was prepared by mixing together molecular quantities of the iodide and silver d-bromocamphorsulphonate with acetone and heating for about

half-an-hour on the water bath, when all the iodide was completely decomposed. After filtering and evaporating off the acetone, the gummy residue readily became crystalline when left in a desiccator. The crystals were readily soluble in acetone and ethyl acetate and sparingly soluble in toluene.

It was recrystallised repeatedly from a mixture of ethyl acetate and a little toluene, when it was noticed that two kinds of crystals separated out, small colourless transparent crystals sparingly soluble in ethyl acetate which when recrystallised several times over from ethyl acetate melted at 164° C., and silky needles readily soluble in ethyl acetate which when pure melted at 153·5° C.

The less soluble salt was readily separated mechanically from the other and was repeatedly recrystallised from ethyl acetate, and its rotatory power in aqueous solution was determined.

After three recrystallisations

0·1598 in 16·028 solution in a 220 mm. tube gave $\alpha_D = 0{\cdot}98°$,

whence $[\alpha]_D = 49{\cdot}1°$ and $[M]_D = 245°$.

After two further recrystallisations

0·1610 in 17·123 solution in a 220 mm. tube gave $\alpha_D = 0{\cdot}81°$,

whence $[\alpha]_D = 39{\cdot}16°$ and $[M]_D = 195°$.

This is evidently the l-base d-acid salt and the value of $[M]_D$ for the basic ion $C_9H_{10} : N\begin{matrix}CH_3\\ \diagup\\ \diagdown\\ C_3H_5\end{matrix}$ is about $-75°$.

The more soluble crystals were then examined, and recrystallised repeatedly from a mixture of ethyl acetate and toluene. The rotatory power was determined in aqueous solution.

0·1678 in 17·457 of solution in a 220 mm. tube gave $\alpha_D = 1{\cdot}45°$,

whence $[\alpha]_D = 68{\cdot}6°$ and $[M]_D = 342°$.

This is therefore the d-base d-acid salt, and the value of $[M]_D$ for the basic ion is $+72°$, which agrees well with the value obtained for the laevo-rotatory ion.

Analysis of both salts shows that they have the same composition corresponding to $C_{23}H_{32}NBr_2SO_4$.

Unfortunately the iodide is fairly soluble in water and could not be recovered from the d-bromocamphorsulphonate. There is no doubt however that the salts obtained are d-allyl kairolinium d-bromocamphorsulphonate and l-allyl kairolinium d-bromocamphorsulphonate, which constitutes the first case of an optically active compound in which the activity is due to a nitrogen atom in a ring.

This work was undertaken at the suggestion of Mr H. O. Jones, to whom the author takes this opportunity of expressing his gratitude for his advice.

The Ethnology of Modern Egypt. By CHARLES S. MYERS, Gonville and Caius College.

[*Read* 11 February 1907.]

The material which serves for the present study* was collected by me in the years 1901 and 1902. During my stay at Abbasia, near Cairo, I measured, described and photographed 1006 Egyptian conscripts; I thus obtained over 17,000 measurements. I am indebted to the Government Grants Committee of the Royal Society and to the British Association for the Advancement of Science, for financial assistance. My hearty thanks are also due to Sir F. R. Wingate, K.C.B., K.C.M.G., Sirdar of the Egyptian Army, who kindly placed at my disposal as many Egyptian and Sudanese troops as I had time to examine.

The object of my work was to determine what differences, if any, exist between (A) the Ancient and Modern Egyptians, (B) the present inhabitants of different parts of Egypt, and (C) the present Moslems and the present Copts†.

A. Comparisons between the Ancient and Modern Egyptians.

I have compared my data with those published by Miss Fawcett and her collaborators‡, and derived from a series of "prehistoric" skulls which Prof. Flinders Petrie excavated at Naḳada. I have carefully selected for comparison only those of my measurements which refer to persons living under the same conditions and in the same part of Egypt as did their "prehistoric" ancestors some seven thousand years ago.

The following table shows the cephalic index and the head-measurements, taken in the "prehistoric" series on the skull, and in the modern series on the living head:—

Series	Head length		Head breadth		Cephalic Index	
	No.	Mean	No.	Mean	No.	Mean
Naḳada ("prehistoric")	139	185·13	139	134·87	130	72·99
Ḳena ("modern")	53	194·79	53	143·91	53	73·94
Girga ("modern").....	83	194·53	83	144·33	83	74·25
Ḳena and Girga ("modern")	136	194·63	136	144·16	136	74·13

* For a more detailed account the reader may be referred to my "Contributions to Egyptian Anthropology," which are appearing in the *Journal* of the Anthropological Institute.

† Egypt was officially proclaimed a Christian country in the reign of Theodosius I, 308 A.D., and remained so until the Moslem invasion of 640 A.D. The Copts are the small section of Egyptians who, refusing to embrace Mahommedanism, have continued to this day steadfast in the former religion.

‡ *Biometrika*, 1902, I. pp. 408—467.

If we deduct 10 mm. from the head length and 10·5 mm. from the head breadth, and a proportionate figure, 1·6, from the cephalic index (these deductions being based on Welcker's investigations*, and allowance being made for the closely-cropped hair of my subjects), the figures then become :—

Series	No.	Head length	Head breadth	Cephalic Index
Naḳada ("prehistoric")	139	185·13	134·87	72·99
Ḳena and Girga ("modern")	136	184·63	133·66	72·53

whence I conclude that *there is no essential difference between the head-measurements of the prehistoric and of the modern population of this region of Egypt.*

A similar conclusion results from the study of the comparative variability of the prehistoric and modern peoples. In the following table, σ expresses the standard deviation, C the coefficient of variability, and each value is followed by its probable error.

Series	Head length			Head breadth		
	No.	σ	C	No.	σ	C
Nakada ("prehistoric")	139	$5·75 \pm 0·23$	$3·17 \pm 0·13$	139	$4·60 \pm 0·19$	$3·29 \pm 0·13$
Ḳena and Girga ("modern")	136	$5·83 \pm 0·24$	$3·00 \pm 0·12$	136	$4·31 \pm 0·18$	$2·99 \pm 0·12$

Series	Cephalic Index			Auricular Height		
	No.	σ	C	No.	σ	C
Nakada ("prehistoric")	130	$2·80 \pm 0·12$	$3·83 \pm 0·16$	140	$4·46 \pm 0·18$	$3·86 \pm 0·16$
Ḳena and Girga ("modern")	136	$3·04 \pm 0·12$	$4·10 \pm 0·17$	64	$4·47 \pm 0·27$	$3·07 \pm 0·18$

Series	Horizontal Circumference			Upper Facial Index		
	No.	σ	C	No.	σ	C
Nakada ("prehistoric")	118	$13·00 \pm 0·57$	$2·54 \pm 0·11$	76	$4·52 \pm 0·25$	$6·41 \pm 0·35$
Ḳena and Girga ("modern")	57	$13·38 \pm 0·84$	$2·45 \pm 0·15$	135	$3·14 \pm 0·13$	$6·53 \pm 0·27$

* Schiller's *Schädel und Todtenmaske*, Braunschweig, 1883, quoted by Lee and Pearson, *Phil. Trans. Roy. Soc.*, 1901, CXCVI. p. 251.

I conclude, then, that *the homogeneity of the Egyptians of this district is the same to-day as it was seven thousand years ago.*

Against the justifiability of this conclusion it may be urged that the modern Egyptians whom I have measured are a picked body of men, chosen for their good physique. But I have also made a special comparison of my modern material with the data obtained from thirty-five of the very tallest skeletons of the Naḳada series; and I have not found any appreciable difference between the selected and the unselected data as regards average head dimensions or as regards the variability of those dimensions.

My last attempt has been to study the coefficients of correlation in the prehistoric and in the modern series (*a*) between length and breadth, (*b*) between length and auricular height, and (*c*) between breadth and auricular height, of head.

Series	No.	Correlation L. and B.	No.	Correlation L. and Au. H.	No.	Correlation B. and Au. H.
Naḳada ("prehistoric")	139	0·344 ±0·050	64	0·404 ±0·071	64	0·174 ±0·082
Ḳena and Girga ("modern")	136	0·082 ±0·057	64	0·237 ±0·080	64	0·379 ±0·072

The above table shows that *length and breadth and length and auricular height of head are much more closely correlated in the prehistoric than in the modern people, while the reverse relation holds in the correlation of head breadth and auricular height.*

B. Comparison of the present inhabitants of different parts of Egypt.

The only significant differences that I have been able to find between the present inhabitants of different parts of the Nile Valley *occur in respect of features which distinguish Negroid from Caucasian peoples.*

The nasal index increases in Egypt as we pass from the more northern to the more southern provinces. Probably the upper facial index decreases and the gnathic index increases in the same direction. The colour of the eye and skin also darkens, and the frequency of spiral and crisp hair increases.

Possibly three provinces, Menufia, Ḳaliubia, and Sharḳia form an exception to these conclusions. But in two of the three provinces a sufficient number of data was not obtained.

After careful analysis of the distribution curves of measurements and indices, I have not found it possible to resolve them

into component curves, each corresponding to an underlying ethnic type.

C. Comparison of the Moslems with the Copts.

The Copts are fairer in eye and in skin colour, have straighter hair and thinner lips than the Moslems. The nasal index among the Copts of Lower Egypt is lower than among those of Upper Egypt. The nasal index among the Copts is lower than among the Moslems. *The Copts are less Negroid than the Moslems.*

General Conclusions.

We have seen that in modern Egypt the Moslem population takes on increasingly Negroid characters as we proceed from the Mediterranean shores towards the First Cataract. Is this the result of more frequent intermarriage with the inhabitants of the Sudan ?

In preparing to answer this question, we cannot neglect the fact that similar differences in degree of Negroid characters appear to exist among the Copts of Lower and Upper Egypt, who are known to have remained free from Sudanese admixture during the past 1300 years. If, then, an increasing amount of Sudanese admixture be the cause of the increasing Negroid character of Upper as compared with Lower Egypt, it is clear that the intermarriage must have occurred at a very remote date, and that its results have been perpetuated since then.

But we may reasonably doubt whether so long a persistence of the effects of intermarriage is possible. From many different quarters we have indications that ultimately an aboriginal people absorbs and exterminates the physical characters of those who come to settle among them. The enormous migrations of Greeks into the Egyptian oasis of the Fayum, beginning about 2500 years ago and ending soon after the start of the Christian Era, have left no trace of an effect to-day on the physique of the modern dwellers in this oasis. The latter have a nasal index which is distinctly higher than that which occurs among the northern provinces of the Delta, and almost identical with the index found in the Nile Valley in the same latitude as the Fayum.

There are many writers on Egyptian ethnology who believe that from time immemorial there have always been at least two races in Egypt, the one Caucasian (Mediterranean or Libyan) the other Negroid, and that to this day both these races are present throughout Egypt although prevalent in different degrees in different regions. Now we may conceivably look for support of such a hypothesis in the following directions.

We should expect that the inhabitants of Middle Egypt, where presumably the two races are present in equal intensity, would

tend to show greater variability than those of extreme Upper or of extreme Lower Egypt, in which one of the two races presumably predominates to the relative exclusion of the other. But as a fact I have found no such tendency whatever. There is no evidence that the peoples of different parts of Egypt differ in homogeneity.

Secondly, we should expect that the frequency curves for the provinces of Upper and Lower Egypt would have a markedly asymmetrical form, the one showing a skew in one direction, the other in the other, while the frequency curves for the provinces of Middle Egypt would approach the symmetrical form. Again, in point of fact, I can find nothing of the kind.

In the third place, we should expect that a series of distribution curves of the same measurement would show identical peaks in different provinces of Egypt, if two races really existed. This identity of peaks I have in general failed to find. Where it occurs, I believe that it cannot possibly be held to indicate duality of race, inasmuch as the peaks lie far too close (*i.e.* are too nearly of identical value) to have arisen from the inclusion of two types and their fluctuations within a single curve. There is indeed little reason to doubt that if only measurements could be taken in adequate number, the various provinces would each afford smooth peakless distribution curves, having in respect of Negroid characters different averages dependent on the latitude of the provinces, but having like variability*.

I contend, then, that from the anthropometric standpoint every province contains a homogeneous population, notwithstanding the fact that the mean measurements vary in degree of Negroidness according to province. On each side of the variable mean, there are fluctuations to like extents in different provinces. There is no anthropometric evidence of duality of race. I consider that in spite of the various infiltrations of foreign blood in the past, modern Egypt contains a homogeneous population, which gradually shifts its average character as we proceed southwards from the shores of the Mediterranean to Nubia beyond the First Cataract. The transition with which we may meet in such a travel, is certainly not one from Egyptian to Sudanese. What transition there is is from the fairer Mediterranean to the more swarthy Nubian population, a very different matter. The effects of Sudanese admixture both in Egypt and in Nubia are almost as patent as they would be in England.

Thus I regard the aboriginal people of Egypt as a homogeneous

* It is highly probable that the peaked curves on which Professor Petrie unhappily bases his racial analyses of Egypt (the Huxley Lecture for 1906) are sheer accidents, due to the examination of an insufficient number of measurements. Cf. *Biometrika*, 1902, Vol. I. p. 441 *et seq.*

folk, showing an inclination to vary in two or three distinct directions, towards the Caucasian, the Negroid, or even the Mongoloid. The same tendency is also shown among the inhabitants of our own shores. There is hardly any test of Negroid or Mongoloid character (save that of colour), which would not embrace a small but a certain number of our most purely bred fellow-countrymen*. Europeans show accidental variations in the direction, for example, of obliquely directed axes of the eyes or of frizzly hair. Such accidental variations I assume to have been present in the aboriginal Egyptian population, and I hold that environment has been the selecting factor which has intensified and made permanent one or other of these accidental variations.

It would, of course, be absurd to say that a broader nose or a more projecting jaw is essential for a longer life in Upper as compared with Lower Egypt. But I believe that correlated with these physical features there are certain unknown physiological factors which make life easier to sustain in the dry, warm weather of Upper Egypt than in the wetter, cooler and more fertile regions near the Mediterranean.

On the other hand, I am far from denying that sporadic admixture with the Sudanese or with Levantine peoples is without effect or that it has not taken place. We may admit the act and the effect of occasional admixture and yet feel convinced that alone such admixture is insufficient to explain the difficulties at issue.

To sum up. *There is no anthropometric (despite the historical) evidence that the population of Egypt, past or present, is composed of several different races. The probabilities are all in favour of the view which regards the Egyptians always as a homogeneous people who have varied now towards Caucasian, now towards Negroid characters according to environment, showing such close anthropometric affinity to Libyan, Arabian and like neighbouring peoples, showing such variability and possibly such power of absorption, that from the anthropometric standpoint no evidence is obtainable that the modern Egyptians have been appreciably affected by other than sporadic Negroid admixture.*

* This fact dispels the following objection adduced by Thomson and McIver in *The Ancient Races of the Thebaid*:—"No one would allow that a negro nose and a European nose are simply legitimate deviations from a single race type. And yet these are the extremes which occur in our series" (p. 50). I contend that extremes do meet and overlap, and that in the case of Egypt the margin of overlapping is still further widened by sporadic Sudanese and Levantine admixture.

An experiment with a pair of Robison ball-ended Magnets. By G. F. C. Searle, M.A., F.R.S., University Lecturer in Experimental Physics.

[*Read* 28 January 1907.]

§ 1. The advantages of the ball-ended magnets devised by John Robison in 1769 were discussed by me in a paper* read before the Cambridge Philosophical Society on Nov. 10, 1902, and further experience has proved the utility of these magnets in the instruction of students. I now describe an experiment in which two Robison magnets are employed.

In an ordinary magnetometer the pivoted magnet is usually so short that its length may be neglected and thus the axis of the magnet may be regarded as a tangent to the line of horizontal magnetic force which passes through the pivot on which the magnet is supported.

If we use a long Robison magnet for the magnetometer we can no longer neglect the length of the magnet when the lines of force in the neighbourhood have sensible curvature, but, at the same time, we gain the advantage of being able to take a fairly exact account of the length of the magnet, since the poles of a Robison magnet may be regarded, with considerable accuracy, as situated at the centres of the spheres.

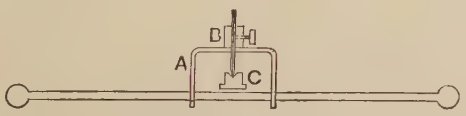


Fig. 1.

A Robison magnetometer is easily constructed in the following manner. A brass U-piece, *A* (Fig. 1), formed of a strip of brass 8 mm. wide and 1 mm. thick, is soldered to a Robison magnet, and this U-piece is provided with a boss *B* through which a sewing needle passes, the needle being secured by a small set screw. The point of the needle rests in an agate cup† *C* carried by an arm of brass *D* projecting from a wooden block *E* as shown in Fig. 2. The block rests upon a drawing board and its height is such that the

* "Notes on a Vibration Magnetometer and on the Ball-ended Magnets of Robison," *Proc. Camb. Phil. Soc.* Vol. XII. Part 1, p. 28.

† Agate centres can be procured from instrument makers at a small cost. A substitute is easily made by heating the sealed end of a piece of small glass tube and then sucking out the air from the other end so as to form a small cup at the heated end.

clearance between the spheres and the drawing board is 3 or 4 millimetres. The set screw is an important feature since it enables the needle to be changed or re-sharpened when its point has deteriorated with use. No satisfactory results are likely to be obtained with a damaged needle-point.

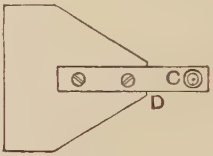


Fig. 2.

In attaching the U-piece to the magnet care is taken that the axis of the needle intersects the axis of the magnet at a point midway between the centres of the spheres. Any small want of balance, due to the magnetic "dip" or to other causes, is corrected by a small rider.

The positions of the centres of the spheres are marked down on the drawing board by aid of a simple optical device. Two straight lines *aob, cod* are drawn by a diamond upon a piece of

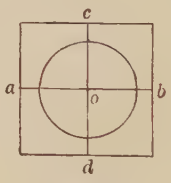


Fig. 3.

mirror glass, as shown in Fig. 3, and a circle, slightly greater in diameter than the spheres of the suspended Robison magnet, is described about *o* as centre. Two of these mirrors are provided, one for each end of the suspended magnet.

A bell jar or other transparent screen is placed over the magnetometer to shield it from draughts. The bell jar rests on three blocks 2 or 3 millimetres high and a strip of thin card passing through the gap is used to move the mirrors into position. They are in adjustment when, on looking vertically down, the observer sees the sphere symmetrically within the circle. The bell jar is then lifted and marks are made on the drawing board at *a, b, c* and *d*. On joining these marks by straight lines the projection of the centre of the sphere on the board is obtained.

§ 2. The magnetometer may be used in an experiment to find the pole strength of a second Robison magnet. This magnet,

which is used to deflect the magnetometer, is placed on the drawing board, each of its spheres resting in a conical depression formed in a heavy brass disk. These disks prevent the magnet from rolling and also raise it to the same level as the suspended magnet. The positions of the centres of the spheres are recorded on the board by pricking the board by a pin passing through a small hole at the bottom of the conical depression.

The magnetometer is first put into position on the board and when the suspended magnet has come to rest in the magnetic meridian, the positions of its poles are observed and recorded, the deflecting magnet being removed to a distance.

The deflecting magnet is then placed near the magnetometer. *Any* position may be chosen as the theory of the experiment is quite general, but the best position is that in which the axis of the deflecting magnet passes approximately through the axis of suspension of the deflected magnet, the axes of the magnets being roughly at right angles. The deflexion should not be less than 30°. The positions of the poles of both magnets are then recorded on the board.

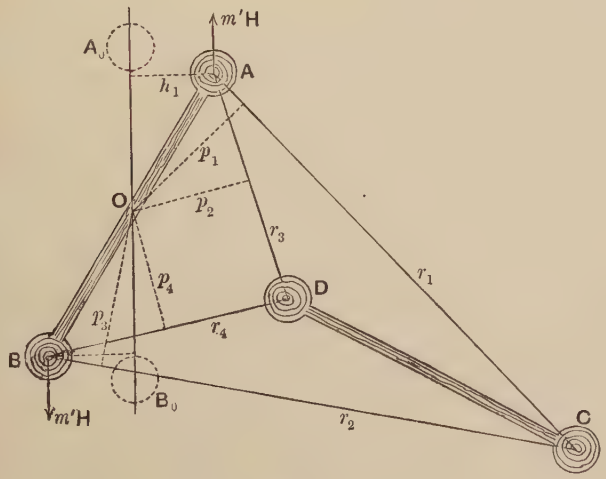


Fig. 4.

Let A_0, B_0 (Fig. 4) be the projections of the poles of the suspended magnet, when undeflected, A_0 being the north pole. Then A_0B_0 marks the magnetic meridian. Let A, B be the projections of the poles of the magnet when deflected and let C, D be the projections of the poles of the deflecting magnet, C being the north pole. Let O be the projection of the centre about which AB turns; this point is determined by the intersection of A_0B_0 and AB.

Let $AC = r_1$, $BC = r_2$, $AD = r_3$ and $BD = r_4$ and let p_1, p_2, p_3 and p_4 be the lengths of perpendiculars from O upon r_1, r_2, r_3 and r_4. Also let the perpendiculars from A and B upon A_0B_0 be h_1 and h_2. Let the pole strength of CD be m and let that of AB be m'.

The force which C exerts on A is mm'/r_1^2 dynes along CA away from C, and its moment about O in the clockwise direction is $-mm'p_1/r_1^2$ dyne-cm. in the case illustrated in Fig. 4. Treating the other three forces in the same way and taking account of the signs of their moments about O, we find that, in the case of Fig. 4, the resultant clockwise moment is

$$mm' \left\{ \frac{p_3}{r_3^2} + \frac{p_4}{r_4^2} - \frac{p_1}{r_1^2} - \frac{p_2}{r_2^2} \right\}.$$

If H be the horizontal component of the earth's magnetic force, the counter-clockwise moment due to the action of the earth is $m'H\,(h_1 + h_2)$. Equating these moments, we have

$$m \left\{ \frac{p_3}{r_3^2} + \frac{p_4}{r_4^2} - \frac{p_1}{r_1^2} - \frac{p_2}{r_2^2} \right\} = H\,(h_1 + h_2) \ldots\ldots\ldots\ldots (1).$$

From this expression m can be found in terms of H when the four distances $r_1 \ldots$ and the six perpendiculars h_1, h_2, $p_1 \ldots$ have been measured.

The value of m deduced from (1) may be compared with that obtained from the readings of an ordinary magnetometer, having a short magnet and provided with a pointer moving over a graduated circle. The instrument should be placed in approximately the same position in the laboratory as the Robison magnetometer so as to avoid errors due to local variations of H.

If the Robison magnet CD produce a deflexion θ, when placed in the "end on" position, and if R_1 and R_2 be the distances of the centres of its spheres from the centre of the magnetometer,

$$m \left(\frac{1}{R_1^2} - \frac{1}{R_2^2} \right) = H \tan \theta \ldots\ldots\ldots\ldots\ldots\ldots (2).$$

The usual precautions should be observed. Thus the magnet should be placed both East and West of the magnetometer and should be turned end for end in each of these positions, while both ends of the pointer should be observed on each occasion. The mean value of the angle deduced from the eight readings is used in (2).

The axis of the Robison magnet should pass through the axis of suspension of the magnetometer magnet. If this adjustment be not secured, the deflexions will differ considerably among themselves.

§ 3. The following results obtained by Messrs F. Phillips and R. Corless will illustrate the working of the method. The value $H = 0{\cdot}176$ gauss was assumed for the earth's horizontal magnetic force. The ten distances were found to be as follows :—

$r_1 = 30{\cdot}66$ cm.	$p_1 = 6{\cdot}91$ cm.	$p_1 r_1^{-2} = 0{\cdot}00735$ cm.$^{-1}$
$r_2 = 28{\cdot}22$ „	$p_2 = 8{\cdot}22$ „	$p_2 r_2^{-2} = 0{\cdot}01032$ „
$r_3 = 16{\cdot}49$ „	$p_3 = 5{\cdot}68$ „	$p_3 r_3^{-2} = 0{\cdot}02088$ „
$r_4 = 13{\cdot}42$ „	$p_4 = 7{\cdot}67$ „	$p_4 r_4^{-2} = 0{\cdot}04258$ „
$h_1 = 3{\cdot}32$ „	$h_2 = 3{\cdot}65$ „	

Hence, by (1)

$$m\{0{\cdot}02088 + 0{\cdot}04258 - 0{\cdot}00735 - 0{\cdot}01032\} = 0{\cdot}176\,(3{\cdot}32 + 3{\cdot}65)$$

or
$$0{\cdot}04579\ m = 6{\cdot}97 \times 0{\cdot}176.$$

Thus
$$m = 26{\cdot}79 \text{ C.G.S. units.}$$

The value of m was also found by an ordinary magnetometer. The eight readings for θ were

41°·9	44°·0	44°·0	42°·0
41°·5	43°·6	43°·6	42°·4

the mean being 42° 52′·5. The corresponding values of R_1 and R_2 were 11·63 and 27·26 cm. Thus

$$R_1^{-2} = 0{\cdot}007393 \text{ and } R_2^{-2} = 0{\cdot}001346.$$

Hence, by (2)

$$m\,(0{\cdot}007393 - 0{\cdot}001346) = 0{\cdot}176 \times \tan 42^\circ\ 52'{\cdot}5.$$

Thus
$$m = 27{\cdot}03 \text{ C.G.S. units.}$$

This result is in good agreement with that obtained with the Robison magnetometer.

The stem of the magnetometer magnet used in these experiments is formed of a knitting needle 0·23 cm. in diameter. The spheres are formed of steel balls $\frac{1}{2}$ inch (1·27 cm.) in diameter, their centres being about 15·7 cm. apart. The balls are first softened and then holes are drilled in them. They are then driven on to the knitting needle and the whole is magnetised in a coil. Further details are given in my earlier paper.

A method of determining the thermal conductivity of Indiarubber. By G. F. C. Searle, M.A., F.R.S., University Lecturer in Experimental Physics.

[*Read* 28 January 1907.]

§ 1. Though the principles of thermal conduction are of great importance in the study of heat, the direct determination of thermal conductivity presents considerable difficulties in the general case and thus there are but few methods of determining thermal conductivity suitable as exercises for elementary students. The difficulties of the subject can, however, be considerably reduced by using solids of very high or of very low conductivity, such as copper, on the one hand, or indiarubber on the other. The determination of the thermal conductivity of copper has been one of the regular class experiments at the Cavendish Laboratory for some years. I now describe a student's method for determining the thermal conductivity of indiarubber, which was originally devised by Mr C. T. R. Wilson and myself to furnish a question in the examination in Practical Physics in Part I of the Natural Sciences Tripos, 1906.

The method is, in principle, applicable to any substance of very low thermal conductivity, and only differs from Péclet's original method by the substitution of a tube for a plate. But the flexibility of an indiarubber tube allows the use of very simple apparatus.

The linear measurements which must be made upon the indiarubber are not capable of any great accuracy, and thus the method must be regarded rather as furnishing a useful illustration of the theory of conduction than as a means of obtaining an accurate value for the conductivity. Yet the results obtained by students, who use the method for the first time, usually agree among themselves to within 5 per cent.

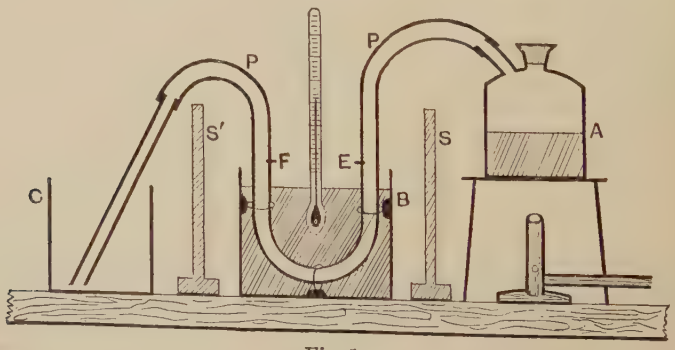


Fig. 1.

§ 2. The apparatus is arranged as in Fig. 1. Steam from the small boiler A flows through the tube of indiarubber P, P, which passes through three rings of wire fixed inside the copper calorimeter B, and finally escapes into the vessel C. The two screens S, S' prevent radiation from A or C from reaching B. The calorimeter contains water, which is kept in motion by a stirrer, and the temperature of the water is observed by a thermometer divided to fifths of a degree. Two marks E, F are made on the tube and the distance between them is measured while the tube is straight, before it is passed through the rings in the calorimeter. The length of tube immersed in the water can then be found by measuring the distances of E and F from the surface of the water when the tube is in place.

The observations are made in the following manner :—

The calorimeter is first dried and weighed and then the indiarubber tube is passed through the rings, care being taken that the tube does not touch the sides of the calorimeter. A beaker is now filled with water five or six degrees below the temperature of the room and is weighed, the weighing being repeated after a sufficient quantity of the water has been poured into the calorimeter ; the difference of mass gives the mass of water in the calorimeter.

During these preliminary observations the water in the boiler has been caused to boil and when the water has been poured into the calorimeter the indiarubber tube is connected to the boiler. When the steam issues freely into the vessel C, the water in B is stirred continuously and the thermometer is read at intervals of one minute, the observations being continued till the temperature has risen four or five degrees above that of the room.

A curve is then plotted showing how the temperature of the calorimeter depends upon the time. When its temperature is equal to that of the room the calorimeter neither loses heat to the room nor gains heat from it. Hence, if we neglect the radiation to the calorimeter from the parts of the indiarubber tube which are not immersed in the water, we may consider that the rate at which the calorimeter gains heat, when it is at the temperature of the room, is equal to the rate at which heat passes by conduction through the part of the tube immersed in the water. The rate of rise of temperature in degrees *per second*, when the calorimeter is at the temperature of the room, is easily found by drawing a tangent to the curve at the proper point.

The ends of the tube, where it is attached to the pipe from the boiler and to the wastepipe, soon become permanently stretched, and hence a short portion should be cut from each end of the tube before the tube is used in the experiment. From measurements made on these portions the internal and external radii of the tube are deduced.

§ 3. Let the mass of the calorimeter be m grammes, let its water equivalent be mc and let the mass of the water in the calorimeter be M grammes. Then, if the temperature of the water rise at the rate of R degrees per *second* when the calorimeter is at the temperature of the room, and if H be the rate at which the calorimeter and its contents then gains heat by conduction through the tube,

$$H = R(M + mc) \text{ thermal units per second.}$$

Since the diameter of the tube is small compared with the radius of curvature of the axis of the tube where it is immersed in the water, we may treat the tube as if it were straight. Hence, if θ be the temperature at any point of the tube at a distance r from the axis and if K be the thermal conductivity, we obtain for a *steady* flow of heat

$$\frac{H}{l} = -2\pi r K \frac{d\theta}{dr},$$

where l is the length of tube immersed in water. If a and b be the external and internal radii of the tube and θ_a and θ_b be the temperatures of the corresponding faces, we obtain

$$\theta_b - \theta_a = \frac{H}{2\pi K l} \log_e \frac{a}{b}.$$

Hence, finally

$$K = \frac{R(M + mc)}{2\pi l(\theta_b - \theta_a)} \log_e \frac{a}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1).$$

Since

$$\frac{1}{2} \log_e \frac{a}{b} = \frac{a-b}{a+b} + \frac{1}{3}\left(\frac{a-b}{a+b}\right)^2 + \ldots$$

it may be sufficiently accurate to write $(a-b)/(a+b)$ for $\frac{1}{2} \log_e (a/b)$. Then

$$K = \frac{R(M + mc)(a-b)}{\pi l(\theta_b - \theta_a)(a+b)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2).$$

It will be seen that to this degree of accuracy the result is the same as if the tube were replaced by a flat plate of thickness $a - b$ and area $\frac{1}{2}\pi l(a + b)$.

The thermal conductivity of indiarubber (0·0004) is only about one-third of that of water (0·0014) and thus we may assume that θ_b is practically identical with the temperature of the steam passing through the tube and that θ_a is practically identical with the temperature shown by the thermometer in the calorimeter, when the water is well stirred.

The amount of heat required to raise the temperature of the tube itself is negligible in comparison with that absorbed by the calorimeter and thus the assumption that the flow of heat is steady leads to no sensible error.

§ 4. The following results, obtained in an actual experiment, will illustrate the working of the method:—

Mass of copper calorimeter and stirrer..... = 162·6 grms.
Water in calorimeter..... = 578·5 grms.
Water equivalent of whole = 578·5 + 162·6 × 0·095 = 593·9 grms.
Length of tube immersed ..... = 15·6 cm.

Two external diameters at right angles were measured at each end of the two portions cut from the tube, and the observations were repeated for the internal diameters. The results were

$2a$ ... 1·06, 1·07, 1·06, 1·07, 1·06, 1·07, 1·06, 1·08,
$2b$ ... 0·62, 0·62, 0·62, 0·61, 0·61, 0·61, 0·60, 0·62,

giving the mean values $a = 0{\cdot}533$ cm., $b = 0{\cdot}307$ cm.

Hence $\log_e (a/b) = 0{\cdot}5517.$

While the steam was passing through the tube the following observations of the temperature of the water in the calorimeter were made:—

Time	Temperature	Time	Temperature	Time	Temperature
min.	°	min.	°	min.	°
32	12·30	37	15·80	42	19·00
33	13·00	38	16·45	43	19·55
34	13·75	39	17·05	44	20·20
35	14·40	40	17·75	45	20·80
36	15·15	41	18·35	46	21·35

The temperature of the room was 16°·5 C. When the temperature was plotted against the time the slope of the curve at 16°·5 indicated that the temperature was rising at the rate of 0·654 degrees per min. Hence $R = 0{\cdot}0109$ degrees per sec.

Inserting the numerical values in (1) we have

$$K = \frac{0{\cdot}0109 \times 593{\cdot}9 \times 0{\cdot}5517}{2\pi \times 15{\cdot}6\,(100 - 16{\cdot}5)}$$

= 0·000436 calories per square cm. per sec. per unit temperature gradient.

If we use the approximate formula (2) we obtain

$$K = \frac{0{\cdot}0109 \times 593{\cdot}9 \times 0{\cdot}226}{\pi \times 15{\cdot}6\,(100 - 16{\cdot}5) \times 0{\cdot}840} = 0{\cdot}000426.$$

A new coloured fluorescent hydrocarbon. By Miss Annie Homer, Bathurst Student of Newnham College, Cambridge. (Communicated by Mr H. O. Jones.)

[*Read* 11 March 1907.]

The products obtained by the action of aluminium chloride on naphthalene at 100° C. have been examined. Among the substances isolated there is a new hydrocarbon which distils above 300° under 10 mm. pressure as a red viscid oil. On cooling the oil sets to a red, transparent, brittle solid, shewing a distinct greenish fluorescence.

Analyses and molecular weight determinations of the hydrocarbon and its nitro derivatives shew that it has the formula $C_{26}H_{22}$. There is some evidence from its mode of formation and reactions that it contains methyl groups; a formula can be suggested in which it is represented as the tetramethyl derivative of a compound $C_{22}H_{14}$ containing five benzene rings and related to naphthalene in the same way as anthracene to benzene. It is proposed to call the new substance *tetramethylerythrene.*

The hydrocarbon is very soluble in benzene, toluene, xylene, carbon bisulphide, carbon tetrachloride, and petroleum ether; fairly soluble in alcohol and acetic acid. In all these solvents its fluorescence is well marked; strong solutions are red with a green fluorescence, dilute solutions yellow with a blue fluorescence.

The hydrocarbon and its solutions were examined spectroscopically. It was found that the hydrocarbon itself absorbed all the blue, green and yellow light up to light of wave-length 5887. General absorption was shewn by solutions stronger than ·02 °/₀, the extent of the absorption increasing as the solutions became more concentrated. In solutions containing from ·00686 to ·00254 grs. of the substance in 100 c.c. of the solvent, two absorption bands were visible, the one in the blue, the other in the violet region of the spectrum.

In solutions containing from ·00686 to ·01886 grs. of the hydrocarbon per cent. and also in solutions containing from ·00254 to ·000846 °/₀ only the band in the blue part of the spectrum was visible. In solutions weaker than ·000846 °/₀ no bands were visible.

The fluorescence of the substance was well marked in solutions containing ·000098 grs. of the hydrocarbon in 100 c.c. of the solvent.

The ultra-violet spectrum of this substance has not been examined as yet.

The bands were measured in solutions of the hydrocarbon in benzene, toluene, xylene, alcohol and glacial acetic acid. In each case ·00508 grs. of the hydrocarbon were dissolved in 100 c.c. of the solvent and the same width of tube was used. Control experiments were done with the solvents used, and in each case the bands were due to the hydrocarbon itself. The position of the second band could not be easily read with the naked eye as it was near the limit of the visible part of the spectrum. Its existence was definitely proved by taking a series of photographs.

The position of the band in the blue part of the spectrum was measured in terms of wave-lengths.

Strength of solution using same width of tube	Solvent	Limit towards the red end. Wave-length	Limit towards the blue end. Wave-length	Maximum Intensity
·00508	Benzene	4448	4379	4425
·00508	Toluene	4446	4385	4425
·00508	Xylene	4447	4390	4423
·00508	Alcohol	4400	4350	4375
·00508	Glacial Acetic Acid	4395	4340	4370

The position of the absorption band is approximately the same for solutions of the hydrocarbon in benzene, toluene, and xylene, whereas it is shifted towards the violet end in solutions in acetic acid and in alcohol.

The second band, for solutions of ·0108 °/₀ strength, lies approximately between the limits $\lambda = 4170$ and $\lambda = 4100$.

Photographs shewed that the strong band in the blue region of the spectrum is in reality a double band. The naked eye was unable to detect the faint line of demarcation between the two constituent bands.

Nitro- and brom-compounds of this hydrocarbon are non-fluorescent in solution.

The Resolution of Salts of Asymmetric Nitrogen Compounds and Weak Organic Acids. By Miss ANNIE HOMER, Bathurst Student of Newnham College, Cambridge. (Communicated by Mr H. O. Jones.)

[*Read* 11 March 1907.]

It was thought advisable to ascertain whether some of the optically active nitrogen compounds could be used for the resolution of weak organic acids. At present the only method available for the resolution of organic acids is the crystallization of their salts with the bases brucine, strychnine, morphine and some synthetic bases. These bases are all very similar and offer little scope for variation, and on account of the weak basic properties of these substances their salts are readily hydrolysed, and especially so those with weak organic acids. The optically active nitrogen compounds are theoretically better suited for the purpose as they are salts of strong bases.

With this object in view an optically inactive iodide was taken, viz. methylphenylbenzylisopropyl ammonium iodide (for preparation see paper by Miss Thomas and Mr Jones, *Camb. Phil. Proc.* 1905). The iodide was dissolved in fifty per cent. alcohol, and treated with slight excess of moist silver oxide. Silver iodide was formed and the substituted ammonium hydroxide left in solution. The liquid was filtered; to the filtrate was added the calculated quantity of (*d*) tartaric acid to form the acid tartrate. The solution was evaporated on a water bath and finally allowed to crystallize in a desiccator over sulphuric acid. The crystals separating out were hygroscopic. After the third crystallization from a mixture of alcohol and petroleum ether, the rotation of the salt was taken and the mother liquors set to crystallize in order to yield enough tartrate for an analysis.

On analysis:

·2315 grs. yielded ·5334 grs. CO_2 and ·1445 grs. H_2O.

$C = 62{\cdot}8\,^{\circ}/_{\circ}$, $H = 6{\cdot}99\,^{\circ}/_{\circ}$.

·1247 grs. „ ·2872 grs. CO_2 and ·0789 grs. H_2O.

$C = 62{\cdot}8\,^{\circ}/_{\circ}$, $H = 7{\cdot}08$.

Theory for $(CH_3C_7H_7C_6H_5C_3H_7N)_2H_4C_4O_6$ requires $C = 72{\cdot}8$, $H = 7{\cdot}64$.

„ $(CH_3C_7H_7C_6H_5C_3H_7N)H_5C_4O_6$ „ $C = 65{\cdot}1$, $H = 6{\cdot}98$.

„ $CH_3C_7H_7C_6H_5C_3H_7NH_5C_4O_6.H_2O$ „ $C = 61{\cdot}9$, $H = 7{\cdot}13$.

The substance is evidently $CH_3C_7H_7C_6H_5C_3H_7NH_5C_4O_6.H_2O$. The high percentage of carbon may be due to the presence of some

of the normal tartrate. As already stated the substance for analysis was obtained from the mother liquors from the third crystallization.

·1014 grs. of the tartrate, three times recrystallized from alcohol and petroleum ether, dissolved in 13·9 c.c. of water, gave a rotation of $+1·533°$ in a two decimeter tube.

Hence $[\alpha]_D = +105°$ and $[M]_D = +427·6°$,

$[M]_D$ for acid tartrates of strong bases $= +24·5°$; therefore $[M]_D$ for the basic ion $= +403·1°$.

This value is slightly above that of the ion of the pure ammonium salt, which is 398°. The rotatory power of the iodide given below shews that the salt has been only partially resolved. The high value for the molecular rotation of the salt is probably due to contamination of the acid tartrate by the normal tartrate which would naturally raise the value of $[M]_D$. The iodide was precipitated from the solution of the tartrate in water by means of potassium iodide.

·1030 grs. of the iodide in 13·0 c.c. alcohol in a two decimeter tube gave a rotation of $+1·17°$; therefore $[M]_D$ for the iodide is $+275°$.

It is therefore evident that the substituted ammonium compound used forms a definite crystalline compound with (*d*) tartaric acid, and that from this the (*d*) base (*d*) tartrate can be separated from the (*l*) base (*d*) tartrate by crystallization. One would therefore expect an optically active nitrogen compound to resolve an inactive organic acid. To test this assumption the author tried to resolve inactive mixtures of (*d*) and (*l*) mandelic acids, and of (*d*) and (*l*) valeric acids by means of active phenylmethylbenzylisopropyl ammonium iodide (Thomas and Jones, *J. C. S.* 1906, p. 280). A calculated quantity of the iodide was dissolved in fifty per cent. alcohol and converted into the optically active ammonium hydroxide as already described.

To the solution of the hydroxide was added the calculated quantity of the acid. It was found that evaporating the solution on the water bath caused complete racemisation to take place. However, if the solutions were allowed to evaporate slowly in vacuum desiccators, crystalline products were obtained. These were recrystallized several times from acetone.

After the third recrystallization of the ammonium mandelate ·1258 grs. in 16·5 c.c. alcohol in a two decimeter tube gave a rotation of $-·364°$. $[M]_D = -93·8°$.

It is probable, since the difference between $[M]_D$ of the salt and the basic ion is greater than that of the pure mandelic ion, that racemisation has occurred while the solutions were evaporating at the laboratory temperature. Before the first crop

of crystals were obtained the solutions stood for some three months or more. With regard to the valerate it was found that after three recrystallizations from acetone and petroleum ether ·103 grs. substance in 12 c.c. water in a two decimeter tube gave a rotation $-1{\cdot}97°$; therefore $[M]_D = -391{\cdot}5°$.

After four crystallizations ·030 grs. substance in 12 c.c. water in a two decimeter tube gave a rotation $-{\cdot}59°$; therefore $[M]_D = -402°$.

The rotation for the active ammonium ion $= -398°$.

In this case racemisation has not occurred, but it is impossible to say whether separation of the two salts had been effected.

The author tried to obtain the active ammonium salts of the acids by treating their silver salts with the active iodide in alcoholic solution, on the water bath at 100° C. Here again there was racemisation.

If the active ammonium hydroxide could be obtained in a concentrated solution before treating with the acid to be resolved, there would be greater chance of the complete resolution of the acid.

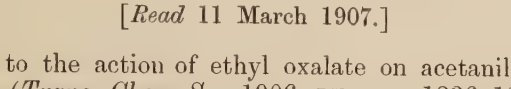
It is almost certain that the failure to resolve mandelic and valeric acids completely is due to the fact that while the solutions cannot be evaporated on the water bath, yet at the ordinary temperatures the liquids have to stand so long before they are sufficiently concentrated for crystals to form that racemisation tends to take place during the process.

This work was undertaken at the suggestion of Mr H. O. Jones, M.A., of Clare College. The author takes this opportunity of thanking him for the kindly interest shewn during the progress of the investigation.

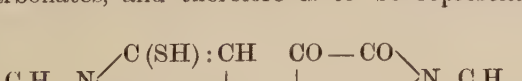
Dithioxanthoxalanil and its Homologues. By S. RUHEMANN, M.A., Gonville and Caius College.

[*Read* 11 March 1907.]

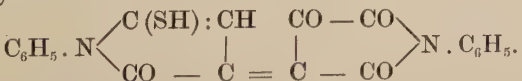
Similar to the action of ethyl oxalate on acetanilide and its homologues (*Trans. Chem. Soc.* 1906, LXXXIX. 1236, 1847) is the behaviour of thioacetanilide and its homologues towards the ester. This reaction yields compounds, the representative of which, *dithioxanthoxalanil*, is to be expressed by the formula:



With regard to their colour I find that they shew similar differences to the corresponding members of the xanthoxalanil group, dithioxanthoxalanil being dark brown, whereas its homologues have a lighter shade. The dithio-derivatives have no acidic properties, and in this respect resemble the other class of compounds; they differ, however, from them by their greater stability towards alkalis. Xanthoxalanil, for instance, on warming with dilute caustic potash, is decomposed, and yields aniline, dianilaconitic acid and oxalic acid. No similar decomposition takes place on digesting dithioxanthoxalanil with the dilute alkali, instead of it the compound is transformed into its tautomeride which readily dissolves in caustic alkalis as well as their carbonates, and therefore is to be represented by the formula:



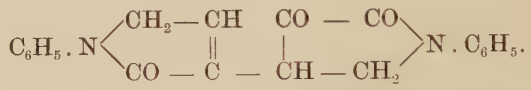
On boiling dithioxanthoxalanil with caustic potash (15—20 per cent.) for some hours, one atom of sulphur is replaced by oxygen and a substance *thioxanthoxalanil* is produced which dissolves in sodium carbonate. This behaviour points to the following symbol:



A complete decomposition of dithioxanthoxalanil does not take place until it is boiled with quite concentrated caustic potash (60—70 per cent.).

Of great interest is the action of reducing agents on dithioxanthoxalanil, which differs from the behaviour of xanthoxalanil and its homologues towards zinc dust and acetic acid (see S. Ruhemann, *Trans. Chem. Soc.* 1906, LXXXIX. 1847).

The latter substances thus add six atoms of hydrogen and yield colourless compounds, but dithioxanthoxalanil is transformed into a substance with the formula $C_{20}H_{16}O_3N_2$. In this case, therefore, no addition of hydrogen takes place; instead of it, the total sulphur is replaced by hydrogen. The facts that this substance is colourless and insoluble in sodium carbonate, lead to the conclusion that the substitution is accompanied by a change of the linking, and that the constitution of $C_{20}H_{16}O_3N_2$ is probably to be represented thus:



On boiling this compound with sodium carbonate, it is transformed into the blue sodium derivative of a red substance, which latter is formed on adding an excess of hydrochloric acid to the blue salt. The behaviour of the red compound—this is most likely isomeric with the reduction product $C_{20}H_{16}O_3N_2$ of dithioxanthoxalanil—resembles the red isomeride $C_{14}H_{12}O_3$ which Ruhemann and Merriman (*Trans. Chem. Soc.* 1906, LXXXIX. 1386) obtained in the course of the study of the reaction between phenylpropiolyl chloride and acetylacetone. This, also, forms blue salts, as does Claisen and Ewan's oxalyldibenzylketone. This resemblance leads to the view that those compounds have to be represented by similar structural formulae. Experiments are in progress with the object of verifying this conclusion.

Note on the influence of extraneous forces upon the proportion of the sexes produced by Canaries. By Walter Heape, M.A., F.R.S., Trinity College, Cambridge.

[*Received* 1 May 1907.]

The careful records on which the following note is based were very kindly supplied to me by two breeders of canaries, Mr Needham and Mr Gentry.

Their results show a remarkable difference in the proportion of the sexes of the young birds produced in these two aviaries, which is consistent both in detail and in the totals.

Such consistent variation, when considered in relation to the food supplied and to the temperature and surroundings to which the birds were subjected, may be interpreted as evidence of the exercise of extraneous forces on the proportion of the sexes produced and of selective action on the generative elements dehisced by the parent birds.

In a former paper ("Note on the proportion of the sexes in Dogs," *Proc. Camb. Philosoph. Soc.*, 1907) I have indicated my reasons for believing that extraneous forces do influence the proportion of the sexes produced by certain animals, and the evidence now presented is, I judge, confirmatory of that view.

In the following account Mr Needham's records will be referred to as *N*, Mr Gentry's as *G*.

Results as shown in Table I.

N. During the years 1888—1893, 11 cocks and 22 hens were bred from. One cock and one hen were "London Fancy" breed, a second hen was cross bred, all the rest were "Lizard" canaries.

These birds formed 71 nests and laid 313 eggs, from which 87 cocks and 113 hens were hatched—a total of 200 chicks. That is, with a loss of 36·1 °/₀ of eggs the proportion of the sexes produced was at the rate of 76·99 cocks per 100 hens.

G. During the year 1892 bred from 4 cocks and 8 hens, all of which were "Lizards" with the exception of one cross bred hen.

These birds made 20 nests, laid 84 eggs from which 53 cocks and 15 hens, a total of 68 chicks, were hatched. That is, with a loss of 19·05 °/₀ of eggs the proportion of the sexes produced was at the rate of 353·3 cocks per 100 hens.

But certain data are available where no loss of eggs occurred.

N had 4 cocks and 9 hens making 11 nests and laying 48 eggs, *all* of which were hatched. These produced 22 cocks and 26 hens, that is at the rate of 84·61 cocks per 100 hens.

G had 4 cocks and 6 hens making 11 nests and laying 48 eggs, *all* of which were hatched. These produced 35 cocks and 13 hens, that is at the rate of 269·23 cocks per 100 hens.

Thus *G*'s birds hatched, and must have produced, a very large excess of cocks, while *N*'s birds are responsible for a marked excess of hens.

Regarding the unfertilised or addled eggs, *N* suffered a much greater proportion of loss than *G*.

The difference between the proportion of cocks and hens produced in *N*'s total results and in the results obtained from those of his nests in which all the eggs laid were hatched, is 7·62 in favour of the latter, and it may therefore be inferred that his losses include more cocks than hens.

G's accurate results, on the other hand, show a decrease of 84·07 cocks per 100 hens when compared with his total results, it may therefore be inferred that he loses more hens than cocks.

At the same time, when the detailed results of both breeders are compared, there is no room for doubt that the losses each experience are not responsible for the wide difference between their results, and it is clear that some influence is at work which profoundly affects the proportion of the sexes produced in these two aviaries.

Details are given in the following Table.

Breeders	Year	Breeding				Produce			Cocks per 100 hens	% of eggs not hatched
		Cocks	Hens	Nests	Eggs laid	Cocks	Hens	Total		
Total Produce *N*	1888	2	2	5	23	5	7	12	71·43	47·83
	1889	3	5	14	57	14	23	37	60·87	35·09
	1890	4	5	13	61	23	25	48	92·0	21·31
	1891	5	6	14	64	15	25	40	60·0	37·5
	1892	4	5	14	58	12	21	33	57·14	43·1
	1893	3	4	11	50	18	12	30	150·0	40·0
	Totals	11	22	71	313	87	113	200	76·99	36·1
G	1892	4	8	20	84	53	15	68	353·3	19·05
Produce of nests in which *all* eggs are hatched *N*	1888	1	1	1	4	1	3	4	33·3	
	1889	2	2	2	8	4	4	8	100·0	
	1890	3	4	6	28	14	14	28	100·0	
	1891	1	1	1	5	2	3	5	66·6	
	1892	1	1	1	3	1	2	3	50·0	
	Totals	4	9	11	48	22	26	48	84·61	
G	1892	4	6	11	48	35	13	48	269·23	

Conditions under which birds were kept.

N's birds were kept in a room facing N. and E., heated by a fire when necessary. In winter the temperature might go down to freezing point; in spring, during breeding time, down to 45° on cold nights. During the day in spring it was usually from 55° to 60°, in summer from 70° to 80°.

There was always a plentiful supply of canary seed in the hoppers; and hemp, rape, and maw seeds, hard boiled egg and biscuit crumb, and green food, was also given in plenty.

With the exception of 2 cocks, which were not hardy, all birds were strong and healthy.

The dates of hatching—taking all years collectively—were as follows: 19·72 °/₀ of the nests in April, 29·58 °/₀ in May, 28·17 °/₀ in June, 21·12 °/₀ in July, and 1·41 °/₀ in August.

The cocks fail in vigour and commence to moult earlier, generally at least a month earlier, than the hens; counting each bird separately each year, 15 cocks moulted in July and 4 in August. Of the hens, 2 moulted in July, 12 in August, 5 in September, and 1 in October.

During 1893 *N* made an experiment with regard to food. Less hard food of all kinds was given, no hard boiled egg at all, and plenty of green food.

This is the only year in which *N*'s produce shows an excess of cocks; viz. at the rate of 150 cocks per 100 hens, with a loss of 40 °/₀ of the eggs laid.

Among the birds used for breeding this year were a pair of birds obtained from *G*. They made 3 nests, laid 15 eggs, and reared 5 cocks and 3 hens, a total of 8 chicks. It is to be noted, however, that two pairs of *N*'s own birds this year reared 8 cocks and 3 hens, a total of 11 chicks, out of 15 eggs.

G's birds were kept in a room facing S., heated by hot water pipes when necessary. In winter the temperature might go down to freezing point, in summer up to 100°. During the breeding time it was kept regularly at 60°.

Similar food was given, but these birds were not so plentifully fed as *N*'s birds, and care was especially taken to avoid over-feeding. Green food was supplied in plenty.

All the birds were strong and healthy.

The dates of hatching were as follows: 25 °/₀ in April, 35 °/₀ in May, 30 °/₀ in June, and 10 °/₀ in July.

One bird moulted exceptionally early, in May, 7 in July, and 4 in August. There was not such a marked difference between the dates of moulting of cocks and hens as in *N*'s aviary.

One pair of these birds, obtained from *N*, made 3 nests, laid 12 eggs, and produced 9 cocks and 1 hen, a total of 10 chicks. The

same cock with one of *G*'s hens is responsible for 3 nests, and 13 eggs, which produced 11 cocks and 2 hens.

Thus to compare the two. In *G*'s aviary a more regular temperature was kept during the breeding time; there was more light and sun in the room; less food was given; hatching and moulting took place earlier as a rule; only about half the percentage of loss was experienced; and from the nests in which all eggs were hatched, the proportion of cocks produced was more than three times the proportion obtained in *N*'s aviary.

It seems clear that while *N*'s birds were highly fed, possibly with the idea of counteracting the uncongenial aspect of the aviary, *G*'s birds attained breeding condition earlier with less food.

While *N*'s birds laid 4·4 eggs per nest, *G*'s laid 4·2; but although *N*'s birds laid more eggs a very much larger percentage of them did not hatch, and it may be concluded *G*'s birds had much the greater reproductive power.

From a comparison of the dates of nesting and of the moulting of the cocks, I am inclined to think the large percentage of loss among *N*'s eggs is principally due to the cocks.

It might be argued that the marked tendency of *G*'s birds to produce an excess of cocks was due to the particular strain of birds he bred from. It is true that when *N* bred from a pair of *G*'s birds the produce hatched was at the rate of 166·6 cocks per 100 hens (more than double the average proportion he gets); but during that year the birds were subject to special feeding and that same year another pair of *N*'s own birds hatched eggs in the proportion of 200 cocks per 100 hens (a proportion which had only three times been equalled by any pair of his birds during the 5 preceding years), and in a third pair, also of *N*'s birds, 400 cocks per 100 hens was the proportion hatched (a unique experience for him). Thus under *N*'s treatment the birds obtained from *G* did not hatch so high a proportion of cocks as did other birds of his own rearing that particular year.

On the other hand, when *G* bred from a pair of birds obtained from *N*, the proportion hatched was at the rate of 900 cocks per 100 hens, and when the cock of this pair was mated with one of his own hens 550 cocks per 100 hens was the proportion actually produced.

So far as the evidence goes therefore it does not appear that the high proportion of cocks hatched in *G*'s aviary is due to the strain of his birds, but to some other factor or factors which influenced all birds kept by him, a conclusion which is borne out by *N*'s experience during 1893.

In a recent paper "On the proportion of the sexes in Dogs," published in the *Proceedings* of this Society, I have suggested that in all animals in which only a limited number of ovarian ova

mature during each breeding season, these ova are subject to selective action, an action with which the quantity or quality of the nutriment supplied has much to do.

Here I suggest that the factors which mainly governed the results shown for these two aviaries were, for *G*, a temperature and aspect which conduced to early breeding and the early maturation of ova which had not received specially rich nutrition. The generative functions of these birds was in fact "forced" without being richly fed and they produced males in great excess.

N's birds, on the other hand, were kept back, they both nested later and moulted later than *G*'s birds, their generative functions were not stimulated, the ova matured more slowly and were at the same time more highly fed, and these birds produced a marked excess of females.

A similar result, obtained by forcing and retarding development in plants, is recorded by Meehan and by Bordage, whose works are noted in my paper on Dogs referred to above.

As a rule in nature the climatic forces which stimulate the activity of the generative functions are also associated with a plentiful supply of food, the conditions which excite the one ensure the supply of the other. Among domesticated animals living in the open air, on the other hand, any forcing of the breeding time is brought about by special feeding. In neither case are the results obtained comparable to those we have now before us, where both the quality and the quantity of the food supplied is regulated entirely independently of the other causes which stimulate the activity of the generative system.

It is to this peculiar combination I attribute the regularity of the remarkable differences shown in these two aviaries.

A curvature method for measuring surface tension. By C. T. R. Wilson, M.A., F.R.S., Sidney Sussex College.

[*Read* 28 January 1907.]

To measure the surface tension of mercury a circular hole of about a mm. in diameter is made through a glass plate closing the upper end of a vertical tube. The tube is filled with mercury, and sufficient pressure is applied to give a suitable curvature to the meniscus projecting into the aperture.

The curvature is measured by making the meniscus serve as a convex mirror. A microscope is focussed (1) on the centre of curvature (when a reflected image of the eye-piece cross-wires will be seen in focus), (2) on a fibre stretched just above the meniscus, (3) on the virtual image of the fibre formed by the meniscus. From the vertical displacements of the microscope between these three positions the radius of curvature is obtained. If the pressure be changed by a known amount between two such measurements of curvature we can deduce the surface tension, for we have

$$2T\left(\frac{1}{r_1}-\frac{1}{r_2}\right)=p_1-p_2.$$

The tendency to fusion shown by the suboccipital vertebrae. By Professor MACALISTER.

[*Read* 25 February 1907.]

A series of ankylosed cervical vertebrae in which there was exhibited a progressive coalescence of the several parts of the occiput and atlas, and of the axis and third cervical vertebra. The stages ranged from a simple adhesion to a complete unification. In one atlas there was a perfect neurocentral articulation between the pedicle and the axial odontoid process on one side.

Some points in the anatomy of the peripheral nerves. By E. BARCLAY-SMITH, M.D., King's College.

[*Read* 25 February 1907.]

Several specimens were exhibited to show that the contour, size and form of the nerve trunks of the body exhibited considerable variation; that these variations were associated with (i) the physical conditions of the tissue traversed by the nerve, (ii) the displacements and strains to which the nerve trunk was subject; that the local enlargements which certain nerves exhibited were due histologically to (i) an accumulation of the intrinsic connective tissue in the nerve trunk, (ii) the presence of numerous Paccinian corpuscles embedded in the nerve fibre bundles of the nerve trunk.

On an occipital vermian fossa and cerebellar vermian eminence. By G. F. Rogers, M.D., Gonville and Caius College. (Communicated by Professor Macalister.)

[*Read* 25 February 1907.]

A median occipital fossa 14 mm. × 35 mm. in the shape of a gutter was shown with a series of varieties ranging from a small triangular flattening at the base of the occipital crest, through triangular fossae of increasing size up to the specimen noted above. The cerebellum belonging to the specimen was also demonstrated to possess an enlarged median lobe, the lateral lobes being separated by a distance corresponding to the breadth of the median fossa. A falx cerebelli was seen on each lip of the groove. Specimens of anthropoid skulls were shown demonstrating the existence of this groove in the gibbon only. A discussion was initiated as to its reputed more frequent appearance in the skulls of criminals, epileptics and lunatics.

On the mode of formation of the initial cell-wall, the genesis and neogenesis of the connecting threads, and the method of connection of living tissue cells. By WALTER GARDINER, Sc.D., F.R.S., Clare College.

[*Read* 11 February 1907.]

Having summarised the existing theories as to the structure of the "initial-wall" of plant cells, and the current view expressed by Strasburger as to the development of connecting threads, the author stated that his own observations appear to prove that the above views are inadmissible.

His observations appear to show that neither the cell-plate nor the initial-wall—which he proposes to call the "cleavage-wall"—can be regarded as homogeneous membranes; but that at the period of division of the cell when the cleavage-wall secreted by the cell-plate is in process of deposition, the cell-plate is still traversed by persistent fibrillar remains. He believes that the cleavage-wall is either perforated by intact fibre nodes or contains within its structure bisected fibre nodes separated by cleavage-wall membrane. In the opinion of the author the fibre nodes or semi-nodes (whichever the case may ultimately turn out to be) are the rudiments or initials of the developing connecting threads, of which the nodes of the several fibres are believed to form the "*loci*." Initial boundary-walls, e.g. those of eggs, spores, etc., probably behave during development like cleavage-walls and may for this purpose be theoretically regarded as free cleavage half-walls.

The author expressed his views on what he believed to be the fundamental significance of the cytoplasmic fibres in relation to mitosis, and urged that all fibres such as supporting fibres, traction fibres, general connecting fibres, and those of suns and asters are in reality homologous and (excepting perhaps traction fibres) may be, and probably are, capable of making provision for the formation of "*loci*" of connecting threads. As to the fibres generally he regards them as being largely of the nature of live scaffoldings which constitute the machinery for mitotic evolutions, cell-wall development, or other matters of cellular *urgency*. The function of the cell-plate is also largely mechanical in that it forms a firm "supporting disk" for the fibres; holding them in position against obvious strain, and making possible the assumption of the spindle figures characteristic of mitosis.

Connection during "sliding growth" is explicable, if it be admitted that there are two *single* walls, each bearing threads, which latter may unite or fail to do so, on the "hit and miss"

principle; and it is not difficult to suggest a working hypothesis to account for "graft union."

Connecting threads may be subsequently obliterated, overlaid or possibly re-formed.

Certain observations and deductions appear to indicate that cells are not in reality necessarily brought into direct protoplasmic continuity by connecting threads, but that the union is in many, if not in most instances, indirect or discontinuous.

It was suggested that the mid or *separation* bodies of certain animal cells described by Fleming and Hoffmann are rather of the nature of *connection* bodies comparable not to the cell-plate but to the connecting threads.

The β Rays from Potassium. By NORMAN CAMPBELL, M.A., Trinity College.

[*Read* 6 May 1907.]

§ 1. In a recent paper Mr Wood and I described some experiments proving that the salts of potassium and rubidium emit ionising rays which appear to be similar to the β rays from uranium. The observations about to be described were undertaken with the object of investigating further the nature of these rays.

It seemed of the first importance to determine whether the rays carry an electric charge. The great penetration of the rays indicates that they cannot be positively charged α rays, but it does not prove decisively whether they are β or γ rays. At first it was hoped that it might be possible to observe a deflection of the rays in a magnetic field by making use of their photographic action, and experiments were made to establish beyond doubt that the photographic action which had been observed previously was not spurious.

§ 2. In the most convincing of these experiments a brass plate 0·3 cm. thick was pierced by a number of holes 0·4 cm. in diameter forming two distinct geometrical patterns. The plate was supported a short distance above a photographic plate* wrapped in light-tight envelopes: covering the holes of one pattern was placed a shallow paper dish containing potassium sulphate, over those of the other a similar dish containing sodium sulphate. After the lapse of eight weeks the plate was developed and it was always found that the pattern covered by the potassium salt was clearly distinguishable, while of that covered by the sodium salt no sign could be seen. This photographic action is interesting, for it can be detected with the simplest apparatus and seems to establish beyond doubt the claim of potassium to be considered one of the radioactive elements.

§ 3. In order to observe the deflection of the rays by a magnetic field it is necessary to interpose a fine slit between the potassium and the plate. Such a slit cuts off such a large proportion of the rays coming from the active material that it was found, by analogous experiments with uranium, that an exposure of many years would be required for the potassium rays to give an impress capable of measurement. This means of determining the presence of a charge on the rays had to be abandoned.

* In the previous experiments Cadett Spectrum plates had been used: unfortunately these plates are no longer obtainable. Five other brands were employed, but with all of them an exposure of eight weeks was required to give a visible impression in place of the three weeks which were sufficient for the Cadett plates.

It did not seem possible to use the ionising effect of the rays for detecting the magnetic deflection: for in order to obtain such an effect of appreciable magnitude a considerable area of the active material has to be employed. To procure a magnetic field of sufficient intensity over so great an area would require the use of special magnets and larger currents than are convenient. It was therefore decided to attempt to observe the deflection of the rays in an electrostatic field—a process which appeared to present fewer practical difficulties. However, the accuracy and rapidity with which measurements can be made was found to be so much greater than was expected, that I think now that it would have been perfectly possible to employ the magnetic effect.

§ 4. The use of the electrostatic deviation has the great disadvantage that it does not permit quantitative measurements of the velocity of the rays to be made. A layer of active material emits rays in all directions: if over such a layer is placed a pair of vertical plates oppositely charged, the electric field between the plates, unlike a magnetic field, does not cause the rays to travel in paths of constant curvature, but merely impresses on them a velocity in the direction of the field. When there is no field acting, the rays which emerge at the top of the plates are those which have been emitted by the layer at a small angle with the vertical: the effect of the field is to substitute for these rays, those which have been emitted at a larger angle with the vertical. The ionising effect of these rays will be less, both because they are fewer in number and because the vertical component of their velocity is less; but unless the rays are homogeneous in velocity and the relation between the intensity of the rays and the angle at which they are emitted from the layer is known, it is impossible to calculate their velocity from an observed decrease of the ionising effect. A limitation of the rays emitted by the layer to those in the vertical direction by suitably arranged slits would reduce so greatly the intensity of the rays that they could hardly be detected. However, it was thought that by comparing the effect of the field on the potassium rays with that on uranium rays, the velocity of which is known, sufficient information could be obtained for the purpose of the research.

Apparatus.

§ 5. The testing vessel in which the ionising effect of the potassium rays was observed was a rectangular box $40 \times 40 \times 22$ cms.: it was lined with lead sheet with the hope of increasing the effect due to the rays by adding to it that of the secondary radiation excited at the walls. One of the larger sides which

formed the bottom of the box was covered with thin aluminium foil 0·0004 cm. thick supported on a brass frame. Under this window was placed the grid of plates for deflecting the rays. This grid consisted of 57 zinc plates each 38 cms. long, 40 wide and ·08 thick: the plane of the plates was vertical and the distance between the inside faces of consecutive plates was 0·6 cm.: the ends of the plates were supported in two long blocks of paraffin wax and were connected to wires so that alternate plates could be joined to opposite poles of a small Wimshurst driven by a motor. Under the grid was placed a glass tray in which the active material was placed: the whole apparatus was placed in a lead-lined box to shield it from accidental radiation.

The Wimshurst was found capable of maintaining a steady P.D. of 8000 volts between the plates: the P.D. could be maintained at any lower value by means of an adjustable point and ball gap placed in parallel with the plates of the grid: it was measured by a Kelvin electrostatic voltmeter. A simple calculation will show that the P.D. of 8000 volts was sufficient to deflect into the plates of the grid all β particles emitted in a vertical direction from the active material with a velocity of not more than $1{\cdot}4 \times 10^{10}$ cms. per sec. It is therefore of the order of magnitude required for these experiments.

§ 6. The saturation current through the testing vessel was measured by the compensation* method which is eminently suitable for the detection of small changes in the current. The pressure in the compensator was adjusted until a balance was very nearly attained and the movement of the leaf of the electroscope in a fixed period (10′) was noted. The Wimshurst was then set in motion and a similar reading taken with a known P.D. between the plates of the grid: the first reading was then repeated and so on, until five readings, two with and three without the field, had been taken. These five readings constitute one observation and occupy about an hour. The difference between the means of the deflections of the leaf with and without the field was a measure of the magnitude of the change of current produced by the field. By observing the difference in the deflection of the leaf on changing the pressure in the compensator by a known amount, this change of current could be found in absolute measure.

It may be of interest to give some idea of the sensitiveness of the method. It appears from the "blank" experiments given below, that a change of half a scale-division in the deflection of the leaf in ten minutes could be detected with certainty: such a change indicates a change in the current of 3×10^{-16} amperes. The saturation current through the testing vessel in the absence of the

* See *Proc. Camb. Phil. Soc.* XIII. p. 132.

potassium is $2{\cdot}7 \times 10^{-13}$ amperes: hence a change of $\frac{1}{9}$ of 1 °/₀ in the spontaneous ionisation current could be detected, or, in terms of radioactive processes, an increase or decrease of one *a* particle emitted every 30 seconds.

Results.

§ 7. The experiment worked more easily than the most sanguine expectations had anticipated.

The current due to the potassium rays coming through the grid in the absence of the field was 280 arbitrary units, or 6·25 °/₀ of the whole ionisation current in the testing vessel. (It must be remembered that the plates of the grid cut off all rays which are not emitted at a small angle with the vertical.) Fifteen observations were taken of the effect of a field corresponding to a P.D. of 8000 volts: they all indicated a decrease of the leak due to the field: the change of deflection of the leaf in ten minutes varied from + 7·7 to + 0·4—mean + 3·8, equivalent to 39 units of current. Therefore the decrease of the potassium rays caused by the field is

$$\frac{39}{280} = 14\ ^{\circ}/_{\circ}.$$

Similar experiments were made with the potassium sulphate replaced by a small packet containing uranium oxide. Two such series were made. In the first the current due to the uranium rays was 1075, the decrease due to the field 62: in the second the current due to the rays was 1275 and the decrease due to the field 90. Hence we have

$$\left.\begin{aligned} \text{Uranium (1) decrease } \frac{62}{1075} &= 6\ ^{\circ}/_{\circ} \\ \text{Uranium (2) decrease } \frac{90}{1275} &= 7\ ^{\circ}/_{\circ} \end{aligned}\right\} \text{ mean } 6{\cdot}5\ ^{\circ}/_{\circ}.$$

Since the decrease caused by the field will vary to some extent with the distribution of the uranium oxide (since on this distribution depends the proportion of the rays which are given out at any particular angle) the difference between the two results need cause no surprise.

§ 8. It was important to perform "blank experiments" with no active material in the tray to make sure that the effect of the field really depended on the presence of charged rays and not on some accidental disturbance. Thirty such blank observations were taken: they were performed in exactly the same way as the rest, except that there was no active material in the tray. The deflections varied from − 5·1 to + 5·0—mean − 0·027, equivalent to 0·28 units of current, less than one per cent. of the change with

the potassium rays. I have no doubt that the extraordinarily small mean obtained for the blank experiments is partly due to chance, but there is an ample margin.

§ 9. A few experiments were made with a less intense field between the plates of the grid. With a P.D. of 5600 volts the following results were obtained.

Potassium rays: decrease $\frac{9}{280} = 3\,\%$.

Uranium rays (1) $\frac{1{\cdot}5}{1075} = 1{\cdot}4\,\%$.

§ 10. At only one stage in the research were any considerable experimental difficulties encountered. Just at the end of the observations anomalous results were obtained. The cause of the trouble was eventually found in brush discharges which had formed at points on the plates of the grid: they had punctured the aluminium window, so that the ionised air in the neighbourhood of the grid could enter the testing vessel and cause an increase in the current. The brushes caused great trouble until the barometric pressure—which had been extraordinarily low—rose, when they disappeared. The hole in the window was mended and the same results as before were obtained.

§ 11. The figures given in § 7 would seem to prove decisively the similarity between the potassium and the uranium rays and to show that the former, like the latter, consist of charged particles. The greater proportional decrease observed with the potassium rays is to be expected if the conclusion of the former experiments is correct, that the rays from potassium are heterogeneous and that their velocity varies from a value approaching that of the extremely rapid rays of uranium down to a much smaller value. It may be noted that the observations on the deflection in smaller electrostatic fields (§ 9) is not quite in harmony with this result, for the ratio of the effect observed with potassium to that observed with uranium is greater for the larger than for the smaller fields. But since the observed decrease in the smaller field does not amount to more than twice the error of experiment the discrepancy is of no importance.

There is a possible alternative to the conclusion that the rays of potassium are β rays: it may be that the charged rays deflected in these experiments are not emitted directly by the potassium, but are secondary rays emitted from the plates of the grid when struck by uncharged rays from potassium. But since this alternative is improbable on *a priori* grounds and explains the experiments no better than the simpler conclusion, I think it may be rejected safely until some positive evidence is offered in support of it.

Summary.

§ 1. The object of the experiments is to prove that the rays from potassium carry a charge and that, since their high penetration forbids the conclusion that they are α rays, they are β rays.

§§ 2—4. After preliminary attempts to observe the magnetic deflection of the rays the method is abandoned in favour of the electrostatic deflection. Incidentally it is proved beyond doubt that the potassium rays can affect a photographic plate.

§§ 5—6. The apparatus used is described.

§§ 7—11. The results show clearly the effects of a deviation of the rays in an electrostatic field and confirm the conclusion of an earlier paper that the potassium rays are β rays of an average velocity less than that of the β rays of uranium.

PROCEEDINGS

OF THE

Cambridge Philosophical Society.

The influence of a strong magnetic field on the spark spectra of lead, tin, antimony, bismuth and gold. By J. E. Purvis, M.A., St John's College.

[*Read* 6 May 1907.]

The author has continued the investigations of the Zeeman effect on the spark spectra of various metals, the results and conclusions of some of which have been already communicated to the Society*. In a preliminary paper describing the apparatus used in the experiments (*Proc. Camb. Phil. Soc.* Vol. xii. Pt ii. p. 82), he gave an account of the *general* effect on the spark spectra of the stronger lines of lead, tin, antimony, bismuth and gold. The experiments have been repeated with these metals, and some of the lines, which then appeared to be widened doublets, have been further separated. The lines of the first four metals were very diffuse and nebulous and there were frequent reversals. Also, the rapid oxidation of the electrodes, when the spark passed between them, produced an irregular discharge, so that the image had never the same clear definition as in metals less easily oxidised. The result was an absence of sharpness in the appearance of the constituents of the divided lines, and the constituents often overlapped when the line divided into more than three, and, occasionally, even when there were only three, so that some of the affected lines appeared to be widened doublets. By using a very narrow slit attached to the spectroscope, by shorter exposures and by introducing a calcite prism between the spark and the focussing lens, in order to separate the constituents vibrating in different planes, some of these doublets have been further subdivided.

But there may be still some doubt in distinguishing between

* *Trans. Camb. Phil. Soc.* Vol. xx. No. viii. p. 193; *Proc. Camb. Phil. Soc.* Vol. xiii. Pt vi. p. 325 and Vol. xiv. Pt i. p. 41.

an ordinary reversal and a separation produced by the magnetic field. The vapour of the metal was pulled out in a direction perpendicular to the line joining the magnetic poles, and the possible production of reversals thereby would interfere with the clear separation of the lines due to the effect of the field alone.

The same apparatus was used as in the earlier experiments. The strength of the field was 39,980 units; the column λ gives the wave length of the undisturbed line; the measured distances between the constituents of the divided lines are omitted, and only the values of $d\lambda/\lambda^2$ calculated therefrom are inserted, and in the same units as employed before; a + sign means that the constituents were on the side of greater wave length, and a − sign of shorter wave length. The column marked "intensity" gives a description of the unaffected lines; the numbers represent the intensities of the lines, the lowest numbers describing lines of greatest intensities, 1 being the strongest; *r* that the lines were often reversed normally, *n* that they were nebulous and *b* that they were broad and wide. The letters *s* and *p* signify, as before, that the constituents vibrated so that their electric vectors were respectively perpendicular or parallel to the lines of force.

It was fairly easy to compare the divided lines when their general appearance was very similar and the number of constituents more than three; there was more certainty in the comparison than when the lines divided into three only. But too much stress should not be laid upon the general appearance of the normal undivided lines because occasionally it happened that lines which were somewhat dissimilar, and particularly in reversals, produced fairly comparable constituents.

Further, it has been noticed before, in the study of other metals, that there were some lines divided into three whose components appeared to be abnormally polarised. It is possible that these were lines yielding five constituents, like Sb 2877·1 (p. 221), and the two extreme ones of which were too weak to be seen or to leave their images on the photographic plate, and the result was the description of a triplet with abnormal polarisation of the constituents.

The lines were identified by comparison with the measurements and descriptions of Exner and Haschek (*Sitz. d. k. Akad. Wien*, Vol. CVI. (1897) II_A. Abth. pp. 54 (Pb), 59 (Sn), 345 (Bi), and 346 (Sb), and Vol. CVII. (1898) p. 792 for Au). As is well known, the metals Pb and Sn are placed in the same chemical family, and Sb and Bi are grouped similarly, and also the four metals have many comparable chemical and physical relationships. In the following notes only the strongest lines of the metals are described; those lines which yielded well marked images after a maximum exposure of 30 minutes when vibrating in the magnetic field.

Lead.

The following lines were divided into four components, but the latter could only be seen well separated on analysis by the calcite. The measurements were between corresponding components.

λ	Intensity	$d\lambda/\lambda^2$	
3740·1	1 *n.*	+2·00 *s* +0·95 *p* 0 −0·95 *p* −2·00 *s*	The four constituents were equally sharp and strong, and comparable with those of 2873·41. Also compare Sb 3722·93 and Sb 3638·01 (p. 221).
2873·41	1	+2·05 *s* +0·97 *p* 0 −0·97 *p* −2·05 *s*	The four constituents were equally sharp and strong, and comparable with those of 3740·1.

The following lines were divided into three ; the middle constituent of each triplet was the strongest, but the exceptions are noted. The measurements were from the centre of the middle constituent.

4387·0	1 *n.*	+1·15 *s* 0 *p* −1·15 *s*	The unaffected lines were strong and nebulous on their less refrangible edges and sharper on the more refrangible. The general appearances of the unaffected lines and of the constituents were very similar. The constituents were all very diffuse, and it was not easy to strike their centres of gravity in the measurements.
4245·2	1 *r.*	+1·31 *s* 0 *p* −1·31 *s*	
4062·30	3	+2·12 *s* 0 *p* −2·13 *s*	
4058·05	1 *r. n.*	+1·81 *s* 0 *p* −1·77 *s*	The middle constituent was a shade weaker than the two outside ones.
3683·6	1 *r.*	+2·15 *s* 0 *p* −2·16 *s*	do.
3671·71	2 *n.*	+1·72 *s* 0 *p* −1·83 *s*	
3639·72	1 *r. n.*	+2·07 *s* 0 *p* −2·04 *s*	The two outside constituents were only a shade weaker than the middle one. They appear to be comparable with those of Sn 3175, 3033, 3009 (p. 220).

λ	Intensity	$d\lambda/\lambda^2$	
3575·95	1 *n.*	+1·96 *s* 0 *p* −1·90 *s*	
2833·18	1 *r.*	+1·96 *s* 0 *p* −1·96 *s*	The middle constituent was removed by calcite before measurement.
2823·28	3	+1·29 *s* 0 *p* −1·29 *s*	The middle constituent was removed by calcite. Exner and Haschek describe the line as 1 *r* : but it was not so strong in my photographs. Compare Sn 2850 (p. 221).
2802·12	1 *r.*	+1·44 *s* 0 *p* −1·44 *s*	The middle constituent was removed by calcite. The constituents are comparable with those of Sn 3261.

Tin.

The line 3330·75 was divided into four; but the constituents could only be seen well separated on analysis by the calcite. The measurements were taken between corresponding constituents.

3330·75	1	+1·79 *s* +1·22 *p* 0 −1·22 *p* −1·79 *s*	The two extreme constituents were weaker and more diffuse than the two middle ones.

The following lines were divided into three components. The middle constituent of each triplet was usually the strongest, but the exceptions are noted.

4524·93	1 *n.*	+1·64 *s* 0 *p* −1·61 *s*	
3801·15	1 *n.*	+1·22 *s* 0 *p* −1·22 *s*	The middle constituent was removed by calcite.
3261·60	1 *r. b.*	+1·50 *s* 0 *p* −1·52 *s*	The two extreme constituents were only a shade weaker than the middle one. They are comparable with those of Pb 2802·12.
3175·17	1 *r. b.*	+2·12 *s* 0 *p* −2·13 *s*	The two extreme constituents were only a shade weaker than the middle one. They are comparable with those of Pb 3639·72 (p. 219).
3033·00	1	+2·12 *s* 0 *p* −2·16 *s*	do.

λ	Intensity	$d\lambda/\lambda^2$	
3009·27	1 *r. b.*	+2·00 *s* 0 *p* −2·02 *s*	The two extreme constituents were only a shade weaker than the middle one. They are comparable with those of Pb 3639·72 (p. 219).
2863·47	1 *r. b.*	+1·95 *s* 0 *p* −1·98 *s*	do.
2850·68	2	+1·30 *s* 0 *p* −1·30 *s*	The middle constituent was removed by calcite. The constituents were weak and diffuse. Compare Pb 2823 (p. 220).
2840·07	1 *r. b.*	+2·00 *s* 0 *p* −2·02 *s*	The two extreme constituents were only a shade weaker than the middle one.
2706·68	1 *r.*	+2·19 *s* 0 *p* −2·22 *s*	do.

Antimony.

The line 2877·1 was divided into five constituents; but they were only seen well separated on analysis by the calcite. The measurements were taken between corresponding ones.

2877·1	1	+2·22 *s* +1·05 *p* 0 *s* −1·05 *p* −2·22 *s*	The middle constituent was much stronger than the other four; the two adjoining ones, vibrating parallel, were about half as strong, whilst the two extreme ones, vibrating perpendicular, were about half as strong as the two vibrating parallel. There is a simple numerical relationship between the constituents, and the numbers are comparable with the quadruplets of 3722·93 and 3638·01.

The following lines were divided into four constituents; and only seen well separated on analysis. The measurements were taken between corresponding ones.

3722·93	2	+2·21 *s* +1·01 *p* 0 −1·01 *p* −2·21 *s*	The constituents were weak, but they were equally sharp and strong. They are comparable with those of 3638·01, Pb 3740·1 and Pb 2873·41 (p. 219).
3638·01	2	+2·11 *s* +0·99 *p* 0 −0·99 *p* −2·11 *s*	do.

λ	Intensity	$d\lambda/\lambda^2$	
2668·90	3 *n.*	+2·26 *s* +1·00 *p* 0 −1·00 *p* −2·26 *s*	The four components were very close to each other; but they appeared to be of equal strength. Their weakness and diffuseness made the measurements rather doubtful.

The following lines became triplets; and the middle constituent of each was stronger than the two outside ones.

3267·60	1	+1·17 *s* 0 *p* −1·19 *s*	The unaffected line was a little stronger than λ 2770·08; otherwise they were very similar in appearance and values of the divided constituents.
3231·60	1	+1·76 *s* 0 *p* −1·75 *s*	Compare Bi 2938·41 and Bi 2898·08.
3029·90	1	+1·95 *s* 0 *p* −2·00 *s*	Compare with Sn 3009.
2770·08	2	+1·20 *s* 0 *p* −1·20 *s*	Compare λ 3267·60, Bi 3397 and Sn 3801.
2598·15	1 *r.*	+1·60 *s* 0 *p* −1·60 *s*	The constituents were weak and diffuse and very close to each other. They were only seen well separated on analysis by the calcite. They appear to be fairly comparable.
2528·62	1 *r.*	+1·59 *s* 0 *p* −1·59 *s*	

Bismuth.

The line 4722·80 was divided into six constituents; but they were only seen well separated on analysis by the calcite. The measurements were between corresponding constituents.

4722·80	1	+2·18 *s* +0·92 *s* +0·65 *p* 0 −0·65 *p* −0·92 *s* −2·18 *s*	The two constituents vibrating parallel were sharper and stronger than the other four; but none of the six were very sharp, and they were all very diffuse.

The following lines were divided into four. The constituents were only seen well separated on analysis; and the measurements were between the corresponding ones.

λ	Intensity	$d\lambda/\lambda^2$	
3024·79	2 *r.*	+1·84 *s* +0·67 *p* 0 −0·67 *p* −1·84 *s*	The constituents appeared to be equally sharp and strong; but they were so very close and diffuse that they were not easy to measure.
2989·15	2 *r.*	+1·99 *s* +0·82 *p* 0 −0·82 *p* −1·99 *s*	The constituents were also very close and diffuse, and not easy to measure, although they appeared to be equally strong. For this reason the comparison with Sb 3722·93 and Sb 3638·01 and Pb 3740·1 and Pb 2873·41 is not very exact, although the general appearances were very similar.

The following lines became triplets: the middle constituent of each was stronger than the two outside ones.

4121·70	2 *r.*	+2·22 *s* 0 *p* −2·29 *s*	
3596·36	1 *r.*	+1·48 *s* 0 *p* −1·48 *s*	The middle constituent was removed by calcite.
3397·42	1 *r.*	+1·30 *s* 0 *p* −1·27 *s*	The three constituents were very diffuse.
2993·45	2	+1·62 *s* 0 *p* −1·61 *s*	
2938·41	1 *r.*	+1·83 *s* 0 *p* −1·86 *s*	Both these lines were very similar in appearance, and their components were also very similar in their diffuseness and intensities. Compare Sb 3231·60.
2898·08	1 *r.*	+1·74 *s* 0 *p* −1·78 *s*	

The line 3067·1 is usually described as a band-like line with a well marked reversal. In the magnetic field there were (1) three well marked constituents; (2) a weak one impinging on the least refracted edge of the least refracted constituent of these three; and (3) a diffuse weak one on the most refracted side of the most refrangible constituent of (1), but not so close as (2). On analysis by the calcite, there were three lines vibrating perpendicular, and two parallel to the lines of force, and the two most refrangible of these five were weaker and more diffuse than the three less refrangible. The explanation appears to be that there was a sharp strong line impinging on the edge of the inside least

refracted edge of a wide reversed band and therefore hidden from view. This strong line has not been described before. It is divided into three, and the reversed band is widened, but whether the latter divided into more than three constituents was not very clear, because the images impinged upon the three stronger constituents of the sharp line: but the most refracted weak line, vibrating perpendicular, and belonging to the reversed band, showed signs of division. The other constituents of the band could not be made out as they were not clear of the three constituents of the line.

Gold.

The following lines were divided into four; the latter could only be seen well separated on analysis by the calcite. The measurements were between corresponding constituents.

λ	Intensity	$d\lambda/\lambda^2$	
3029·31	3	+2·15 *s* +0·99 *p* 0 −0·99 *p* −2·15 *s*	The four constituents were equally sharp and strong; and the general appearance is comparable with Pb 3740·1, 2873·41 (p. 219) and Sb 3722·93, 3638·01 (p. 221).
2676·10	1 *r.*	+1·95 *s* +1·06 *p* 0 −1·06 *p* −1·95 *s*	The four constituents were more diffuse than those of 3029·31.

The following lines were divided into three; the middle constituent of each triplet was stronger than the two outside.

4792·79	3 *r.*	+1·77 *s* 0 *p* −1·83 *s*	
4065·25	1	+1·15 *s* 0 *p* −1·15 *s*	The middle constituent was removed by calcite.
3898·00	1 *r.*	+2·17 *s* 0 *p* −2·12 *s*	Compare λ 2913·68, Bi 4121, Sb 3029.
3804·20	5	+2·18 *s* 0 *p* −2·21 *s*	Compare λ 2748.
3586·84	3 *b.*	+1·62 *s* 0 *p* −1·62 *s*	The line 3586·84 is diffuse on the more refrangible edge. The middle constituent was removed by calcite.

λ	Intensity	$d\lambda/\lambda^2$	
3122·97	1	+1·72 *s* 0 *p* −1·65 *s*	
2913·68	1	+2·01 *s* 0 *p* −1·98 *s*	Compare λ 3898.
2748·30	6	+2·17 *s* 0 *p* −2·19 *s*	Compare λ 3804.

Runge and Paschen have shown that the constituents of some of the lines in the principal and subordinate series of Na, Cu, Ag, Al, Tl, Mg, Ca, Sr and Ba belong to the same type in the character, relative intensity, polarisation and distance apart when represented on the same scale of vibration numbers*. Some of the constituents of the lines of the metals of this investigation appeared to be very similar to several of those described by Runge and Paschen. The author has measured the separation of the constituents of the quadruplets arising from the lines of Cu 3274 and Ag 3383, when the latter were vibrating in the stronger magnetic field used in these experiments, and compared them with several of the divided lines of Pb, Sb and Au. The lines Cu 3274 and Ag 3383 of the principal series were divided into four constituents, and the type, intensity, polarisation and values of $d\lambda/\lambda^2$ are strictly comparable with similar lines of Na, Al, Tl, Mg, Ca, Sr and Ba. The following table is a summary of the comparison of the quadruplets arising from the metals investigated by the author, from which it will be seen that there is a definite relationship between lines belonging to the principal series of Cu and Ag (and, therefore, of Na, Al, Tl, etc.) and lines of Pb, Sb, and Au which have not hitherto been correlated in any law of series.

Cu. 3274	Ag. 3383	Au. 3029	Pb. 3740	Pb. 2873	Sb. 3722	Sb. 3638	Mean
+2·03	+2·05	+2·15	+2·00	+2·05	+2·21	+2·11	+2·08 *s*
+0·97	+0·96	+0·99	+0·95	+0·97	+1·01	+0·99	+0·98 *p*
0	0	0	0	0	0	0	0
−0·97	−0·96	−0·99	−0·95	−0·97	−1·01	−0·99	−0·98 *p*
−2·03	−2·05	−2·15	−2·00	−2·05	−2·21	−2·11	−2·08 *s*

* *Astrophysical Journal*, Vol. xvi. 1902, p. 123.

Within the limits of experimental error the ratio of these numbers is as 1 : 2. The tendency of Sb, Pb, Bi and Sn to produce reversals of the lines, and the diffuseness and closeness of the constituents of lines of high refrangibility, interfere with very exact measurements; so that although the constituents of the lines Au 2676, Sb 2668, and Bi 2989 are not unlike the above quadruplets, the values of $d\lambda/\lambda^2$ are not so strictly comparable.

It is also of some interest to call attention to a relationship between the constituents of certain of the triplets vibrating perpendicular to the lines of force and those of the quadruplets also vibrating perpendicular. For example, the mean values of $d\lambda/\lambda^2$ for the constituents of the triplets of Pb 4062, 3639, 3575, 2833; Sn 3175, 3033, 3009, 2840, 2706; Sb 3029; Bi 4121; Au 3898, 2913 is $+2{\cdot}02\,s$: $-2{\cdot}02\,s$, and these numbers are comparable with the mean values of the corresponding lines of the quadruplets of Cu, Ag, Au, Sb and Pb, which are $+2{\cdot}08\,s$: $-2{\cdot}07\,s$. In connection herewith attention may be drawn to the relationship between the constituents of the quintuplet of Sb 2877 (p. 221), and the corresponding ones of the quadruplets.

General Results.

The more important results of the preceding observations are:—

(1) If the metals Pb, Sn, Sb, Bi and Au are considered *separately*, there are lines comparable with each other in belonging to the same type: *i.e.* they have the same number of constituents, the ratio of the intensities is the same, and also the polarisations and values of $d\lambda/\lambda^2$. The comparison is particularly noticeable amongst the quadruplets. It is also observable amongst the triplets, although, of course, the comparison cannot be so rigid.

(2) If these elements are compared *with one another*, there are lines dividing into four and three which are similarly comparable. And this relationship is again well marked amongst lines of the various metals which become quadruplets.

(3) There are lines in the spectra of Au, Sb and Pb which are also comparable with certain series lines of Ag and Cu. Attention is called above to lines in the principal and subordinate series of Na, Cu, Ag, Al, Tl, Mg, Cu, Sr and Ba which belong to the same type as described by Runge and Paschen. And one of the outstanding facts of the present investigation is that there are lines in the spectra of Au, Pb and Sb also belonging to this type. The lines of the latter metals have not hitherto been correlated with any law of series: and the results show that there are lines of widely

separated elements which belong to the same type, in that they are divided into the same number of components having similar appearances, and whose relative intensities, polarisations and distances apart when represented on the same scale of vibration numbers, are essentially identical.

(4) The constituents of some of the triplets, vibrating perpendicular to the lines of force, are comparable with the constituents of some of the quadruplets of the various metals, in being polarised in the same direction and in having the same distances apart when represented on the above scale of $d\lambda/\lambda^2$.

I wish again to express my thanks to Professor Liveing for the use of his spectroscope.

A representation of the exponential function as an infinite product. By G. B. MATHEWS, M.A., F.R.S., St John's College.

[*Received* 23 April, 1907.]

Let z be a quantity of which the absolute value is less than unity, and let us assume that constants k_1, k_2, etc. can be found such that

$$z = k_1 \log(1+z) + k_2 \log(1+z^2) + \dots$$
$$= \sum_1^\infty k_n \log(1+z^n). \qquad (1)$$

Expanding the logarithms in power-series, and equating coefficients, we find that

$$k_1 = 1,$$

while for all higher values of n

$$k_n + \Sigma \frac{(-1)^{\delta'-1}}{\delta'} k_\delta = 0$$

with $\delta\delta' = n$, $\delta < n$, and each proper integral factor of n supplying one term to the sum.

Hence $$nk_n = \Sigma (-1)^{\delta'} \delta k_\delta = \Sigma (-1)^{n/\delta} \delta k_\delta, \qquad (2)$$

by means of which the constants may be calculated. Experiment suggests the truth of the following statements, which will be confirmed by an inductive argument.

(i) If $n = 2^m$, $k_n = \frac{1}{2}$.

(ii) If $n = p_1 p_2 \dots p_\mu$, $k_n = \dfrac{(-1)^\mu}{n}$.

$p_1, p_2, \dots p_\mu$ being different odd primes.

(iii) If $n = 2^m p_1 p_2 \dots p_\mu$, $k_n = \dfrac{(-1)^\mu 2^{m-1}}{n}$.

(iv) If n has an odd square factor, $k_n = 0$.

Cases (i) and (ii) are easily proved: thus by (2), if $n = 2^m$,

$$nk_n = \Sigma \delta k_\delta = \tfrac{1}{2}\Sigma\delta' + 1 \qquad (\delta' = 2, 4, \dots 2^{m-1})$$
$$= (2^{m-1} - 1) + 1 = \tfrac{1}{2}n,$$

assuming the formula to hold for lower values of m: and since $k_2 = \frac{1}{2}$, the statement (i) is correct.

Again, if $n = p_1 p_2 \dots p_\mu$, every divisor of n is a product of different odd primes, and if h is the number of primes which divide δ_h, any proper divisor of n, we assume that the formula (ii) holds for it, and thus obtain from (2)

$$nk_n = -\Sigma(-1)^h \qquad [h = 0, 1, 2, 3, \ldots (\mu - 1)]$$
$$= -1 + \mu - \frac{\mu(\mu-1)}{2} + \ldots$$

to μ terms, because there are as many divisors δ_h as there are combinations of μ things h at a time. Hence

$$nk_n = -(1-1)^\mu + (-1)^\mu = (-1)^\mu,$$

in accordance with formula (ii): and since, when $\mu = 1$, we have $k_n = -1/n$, this case is proved in general.

To prove case (iii), suppose first that $m = 1$, and write $n = 2P$. Then by (2)

$$nk_n = \Sigma\delta k_\delta - \Sigma 2\delta k_{2\delta} + Pk_P,$$

where the sums apply to all the proper divisors of P. Assuming (ii) and (iii) to hold good for the right-hand side,

$$nk_n = Pk_P = (-1)^\mu,$$

because, by hypothesis, $k_\delta = 2k_{2\delta}$.

Next suppose $m = 2$, and write $n = 4P$. Then, with the same notation, we obtain from (2)

$$nk_n = \Sigma\delta k_\delta + \Sigma 2\delta k_{2\delta} - \Sigma 4\delta k_{4\delta} + Pk_P + 2Pk_{2P}$$
$$= (-1)^{\mu-1} + (-1)^{\mu-1} - 2(-1)^{\mu-1} + (-1)^\mu + (-1)^\mu$$
$$= 2(-1)^\mu.$$

Similarly, for $m = 3$,

$$nk_n = \Sigma\delta k_\delta + \Sigma 2\delta k_{2\delta} + \Sigma 4\delta k_{4\delta} - \Sigma 8\delta k_{8\delta}$$
$$+ Pk_P + 2Pk_{2P} + 4Pk_{4P}$$
$$= (1 + 1 + 2 - 4)(-1)^{\mu-1} + (1 + 1 + 2)(-1)^\mu$$
$$= 4(-1)^\mu,$$

and it is now easy to see that formula (iii) is correct, because when $n = 2p$, $4p$ respectively, p being an odd prime, formula (2) gives results in accordance with (iii).

To prove (iv), put

$$n = p^h m \qquad (h > 1)$$

where p is an odd prime, and m is prime to p. Let $2^\alpha P$ be the greatest factor of m which has no odd square divisor. Then assuming the truth of (iv) for all integers less than n, equation (2) may be written

$$nk_n = \Sigma(-1)^{n/\delta}\delta k_\delta + \Sigma(-1)^{n/p\delta} p\delta k_{p\delta},$$

where the summation extends to all divisors of $2^\alpha P$, including this number itself. Now

$$(-1)^{n/p\delta} = (-1)^{n/\delta},$$

because p is odd; and by formulas (ii) and (iii)

$$p\delta k_{p\delta} = -\delta k_\delta:$$

hence

$$nk_n = \Sigma(-1)^{n/\delta}\{\delta k_\delta + p\delta k_{p\delta}\} = 0.$$

Proceeding from logarithms to exponentials,

$$\left.\begin{aligned} e^z &= \prod_1^\infty (1+z^n)^{k_n} \\ &= (1+z)\,(1+z^2)^{\frac{1}{2}}\,(1+z^3)^{-\frac{1}{3}}\,(1+z^4)^{\frac{1}{2}}\ldots \end{aligned}\right\}, \qquad (3)$$

and if we make use of the formula

$$1 = (1-y)\,(1+y)\,(1+y^2)\ldots(1+y^{2^n})\ldots$$

this can be transformed into

$$e^z = \left(\frac{1+z}{1-z}\right)^{\frac{1}{2}} \Pi \left(\frac{1+z^P}{1-z^P}\right)^{\frac{(-1)^\mu}{2P}}, \qquad (4)$$

where $P = p_1 p_2 \ldots p_\mu$, a product of μ different odd primes, and we are to take all such values of P. Thus, writing out the first few factors in the order of magnitude of P,

$$\begin{aligned} e^z = &\left(\frac{1+z}{1-z}\right)^{\frac{1}{2}} \left(\frac{1+z^3}{1-z^3}\right)^{-\frac{1}{6}} \left(\frac{1+z^5}{1-z^5}\right)^{-\frac{1}{10}} \left(\frac{1+z^7}{1-z^7}\right)^{-\frac{1}{14}} \left(\frac{1+z^{11}}{1-z^{11}}\right)^{-\frac{1}{22}} \\ &\times \left(\frac{1+z^{13}}{1-z^{13}}\right)^{-\frac{1}{26}} \left(\frac{1+z^{15}}{1-z^{15}}\right)^{\frac{1}{30}} \left(\frac{1+z^{17}}{1-z^{17}}\right)^{-\frac{1}{34}} \left(\frac{1+z^{19}}{1-z^{19}}\right)^{-\frac{1}{38}} \\ &\times \left(\frac{1+z^{21}}{1-z^{21}}\right)^{\frac{1}{42}} \left(\frac{1+z^{23}}{1-z^{23}}\right)^{-\frac{1}{46}} \ldots . \end{aligned}$$

The formulas (3) and (4) give good illustrations of function-theory. They are only valid for $|z|<1$, and the behaviour of the products on the right hand when $|z| \geqslant 1$ requires special examination. If

$$\phi_n(x) = \prod_1^n (1+x^n)^{k_n},$$

we have

$$\phi_n(x^{-1}) = x^{-\lambda}\phi_n(x)$$

where

$$\lambda = \sum_1^n n k_n.$$

Now λ is always an integer, when it is not zero; it is found by calculation that $\lambda = 0$ for $n = 7$, 12, so that

$$\phi_7(x^{-1}) = \phi_7(x), \quad \phi_{12}(x^{-1}) = \phi_{12}(x).$$

There are no other values of n below 101 for which $\lambda = 0$: the values of λ, for successive values of n, fluctuate in a curious manner which might repay examination, and there may possibly be an unlimited number of values of n for which $\lambda = 0$. Apparently, $\phi_n(1)$ converges to the value e.

On the transmission of Earthquakes through the Earth. (Second paper.) By Rev. O. Fisher, M.A., F.G.S., Hon. Fellow of Jesus College.

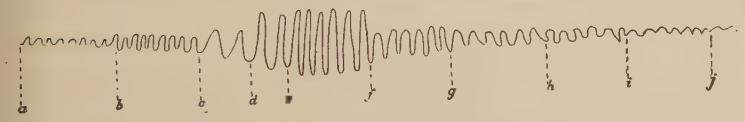
[*Received* 26 April, 1907.]

In a paper published in the *Proceedings of the Cambridge Philosophical Society* (Vol. XII., Pt v., 1903) I endeavoured to explain the transmission of a world-shaking earthquake. I assumed the substratum of the earth's crust to be a liquid magma holding water-gas in solution in accordance with Henry's law, and attributed the primary disturbance to a sudden diminution of pressure. I suggested that the first phase of the record at a distant station might be attributed to an elastic wave propagated in the magma before the pressure had fallen sufficiently for the evolution of gas, and that the second phase might be due to a succeeding wave caused by the evolution of gas as the pressure fell still further.

This theory has met with a certain amount of commendation, and this has led me to enquire whether the relative characteristics of the two phases on this hypothesis would at all agree with the observed facts.

What these are is concisely shown in the subjoined diagram reduced from Prof. Omori's article in *Publications of the Earthquake Investigation Committee*, No. 13, Tokyo, 1903.

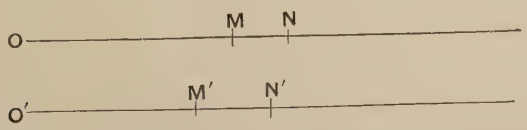
Pendulum record of a distant earthquake (Prof. Omori).



"*ab*, First preliminary tremor [elastic wave].
bc, Second " " [gaseous wave].
cdefg, Principal portion.
j, End portion."

ab is the first phase, and *bc* the second phase. These are transmitted through the interior of the earth. *defghij* are transmitted round the surface supposed by gravity. The end portion has not been explained.

Consider a column of the magma



Let $OM = x$ in the undisturbed state. Since the disturbance at the origin is supposed to consist in a fall of pressure, when the

effect of this reaches M the magma beyond it will expand, and M will be urged towards the origin.

Let P be the pressure at M in the undisturbed state: p that at M'. Let $OM' = x - \xi - \zeta$, where ξ is the expansion at M' due to the elasticity, and ζ that due to the evolution of gas. Let e be the coefficient of voluminal compression of the magma. Also let Π be the pressure corresponding to the limit of elasticity at which gas will begin to be evolved.

Referring to the paper of 1903 it will be seen that for the first and second types of waves we shall have respectively the equations

$$-\frac{1}{e}\frac{dp}{dx} = \frac{d^2\xi}{dx^2}, \tag{1}$$

and

$$-\frac{r}{\Pi}\frac{dp}{dx} = \frac{d^2\zeta}{dx^2}, \tag{2}$$

the differential equations to the two types of wave being respectively

$$\frac{D}{e}\frac{d^2\xi}{dt^2} = \frac{d^2\xi}{dx^2}, \tag{3}$$

and

$$\frac{rD}{\Pi}\frac{d^2\zeta}{dt^2} = \frac{d^2\zeta}{dx^2}, \tag{4}$$

where D is the density and r the ratio of the volume of gas which can be held in solution in accordance with Henry's law.

For the sake of illustration we may suppose the waves to be of the harmonic form. Then

$$\xi = -a \sin\frac{2\pi}{\lambda}x, \tag{5}$$

ξ being negative because M' is urged towards O. Then a is the maximum displacement, and λ the wave's length, so that a/λ will be the ratio of the maximum displacement to the wave's length. Then

$$\frac{d\xi}{dx} = -a\frac{2\pi}{\lambda}\cos\frac{2\pi}{\lambda}x.$$

Also from (1),

$$\frac{d\xi}{dx} = -\frac{p}{e} + C,$$

$$\therefore \frac{p}{e} - C = a\frac{2\pi}{\lambda}\cos\frac{2\pi}{\lambda}x.$$

When $\xi = 0$ there will be no disturbance, and p will have the undisturbed value P. Then by (5) $x = 0$.

Hence

$$a\frac{2\pi}{\lambda} - \frac{a2\pi}{\lambda}\cos\frac{2\pi}{\lambda}x = \frac{P-p}{e}, \tag{6}$$

and $\frac{a4\pi}{\lambda}$ will be the greatest value of $\frac{P-p}{e}$, which will occur when $x=\frac{\lambda}{2}$, *i.e.* at half the wave's length.

If at this juncture the pressure has fallen to the point at which gas begins to be evolved, it is clear that the greatest value possible for a/λ will be $\frac{P-\Pi}{4\pi e}$. And since e, which is the coefficient of voluminal compression at the pressure P, is a very large quantity, therefore a/λ will be a very small ratio, and the characteristic of the wave will be a very slight disturbance and flatness.

In like manner, if we assume the wave of the second phase due to the evolution of gas, to be expressed by

$$\zeta=-b\sin\frac{2\pi}{\mu}x,$$

observing that Π is the highest pressure at which gas is evolved, we have

$$b\frac{2\pi}{\mu}-\frac{b2\pi}{\mu}\cos\frac{2\pi}{\mu}x=r\frac{\Pi-p}{\Pi},$$

consequently the greatest value of $r\frac{\Pi-p}{\Pi}$ is $\frac{b4\pi}{\mu}$, which will occur when $x=\frac{\mu}{2}$; *i.e.* at half the wave's length.

Hence we have the proportion

$$\frac{b}{\mu}:\frac{a}{\lambda}::r\frac{\Pi-p}{\Pi}:\frac{P-\Pi}{e}$$
$$::\frac{re}{\Pi}:\frac{P-\Pi}{\Pi-p}.$$

From (3) and (4) we know that re/Π gives the ratio of the squares of the velocities of the two phases of wave, viz. $(11/5{\cdot}2)^2$ or 4·3 nearly, as observed at distant stations.

Therefore $$\frac{b}{\mu}:\frac{a}{\lambda}::4{\cdot}3:\frac{P-\Pi}{\Pi-p}.$$

$P-\Pi$ being the extreme fall of pressure which corresponds to the limit of elasticity of the magma, it follows that, if the fall of pressure does not exceed this, only the elastic wave would be produced, and it seems probable that it might die out before reaching a distant station. But if the fall of pressure at the origin of disturbance exceeds $P-\Pi$, a gaseous wave will be also produced, and to whatever distance this may be propagated, an elastic wave will be started in front of it, but the magnitude of the latter can never exceed $\frac{P-\Pi}{4\pi e}$.

The case of the second phase—the gaseous wave—will be different. Its greatest magnitude as measured by b/μ will be $r(\Pi - p)/4\pi\Pi$, and will accordingly be proportional to the fall of pressure below that at which gas begins to be evolved.

The above proportion shows that if the further fall of pressure, $\Pi - p$, is no greater than that which has produced the elastic wave, *i.e.* if $\Pi - p$ equals $P - \Pi$, even then the second phase would be four times as large as the first.

It would appear from the above that, if the theory is true, for a given distance of the origin the preliminary tremors ought to be no greater for great earthquakes than for lesser ones, but the magnitude of the second phase ought to be in proportion to the strength of the shock.

The purport of my former paper was primarily to meet the argument for rigidity of the earth's interior based upon the assumption that the waves of the second phase are distortional. In this connection, if we take into account the total expansion of the magma arising both from elasticity and the extrusion of gas, and if we assume for illustration the resulting wave to be of the type expressed by

$$c \sin \frac{2\pi}{\lambda}(ut - x),$$

where $u = \sqrt{\dfrac{eP}{D(er + P)}}$; we obtain in like manner as in equation (6)

$$P - p = \frac{eP}{er + P} \frac{2\pi}{\lambda} c \operatorname{versin} \frac{2\pi}{\lambda}(ut - x).$$

This function satisfies the condition

$$\frac{d^2(P - p)}{dt^2} = u^2 \frac{d^2(P - p)}{dx^2},$$

and therefore represents a single wave of stress, propagated with the velocity u, or $\sqrt{\dfrac{eP}{D(er + P)}}$, and not followed by another*.

The disturbance of pressure having been once started, its propagation through the medium would depend upon the physical properties of the medium, which in the case supposed are expressed by r, e, and D; and we see that its velocity u would be less than $\sqrt{\dfrac{e}{D}}$ that of the elastic wave, or than $\sqrt{\dfrac{P}{rD}}$ that of the gaseous wave.

It results that the original impulse would be propagated as a solitary wave through the magma, which would excite two series of

* See Airy's *Undulatory Theory of Optics*, 1877, p. 19, note.

waves in the substance in front of it as it advanced. It would arrive at a station producing a large movement following the two preliminary phases, which would depend in magnitude and period upon the character of the original impulse. This solitary wave possibly causes the "shock" recorded in seismograms in the case of nearer earthquakes, and may perhaps have some connection with the one or two waves of slow period shown at *cd* in Prof. Omori's diagram.

Mr Oldham in his article in the *Quarterly Journal of the Geological Society* for August, 1906, though referring somewhat favourably to my theory, nevertheless says: "We know nothing of the behaviour of matter exposed to the pressures prevailing in the interior of the earth, and it is not wholly inconceivable that a fluid under pressure of millions of atmospheres might be enabled to transmit the distortional waves, which it is unable to transmit under pressures with which we are familiar." It seems however to be a question also of temperature. As in the case of a liquid and its vapour there is a certain critical temperature at and above which no pressure however great will produce condensation*, so it seems probable that there may be a critical temperature for the fusion of a solid, above which no pressure would reconvert the liquid into a solid. This may possibly be the case within the earth; and although pressure under such circumstances might so increase friction among the molecules as to oppose the deformation of an element of it, yet, supposing that to occur, and that (say) a cube of it has been distorted into a rhombohedron, there seems no reason why pressure should impart that resiliency which would cause the volume in question to return to its original shape, and without this property it could not transmit a distortional wave. In fact resiliency after shear implies solidity. Consequently if there is a liquid layer, however thin, beneath the earth's crust, distortional waves, if existing in the interior, could not be transmitted through it to the surface rocks; and it must be remembered that, even if it could, it is the movements of the heterogeneous matter of these which are instrumentally recorded, and it is hardly to be expected that they should reproduce in kind the movements of the interior, even if responding in period and intensity.

* Maxwell's *Heat*, 5th ed. p. 119.

The Selective Absorption of Röntgen Rays. By G. W. C. Kaye, B.Sc., A.R.C.Sc. (Lond.), Trinity College, Cambridge. (Communicated by Prof. J. J. Thomson, F.R.S.)

[*Read* 6 May 1907.]

McClelland* has shown that there is a close connection between the secondary radiation given out by a substance exposed to the β and γ rays from radium, and the atomic weight of the substance. More recently Prof. J. J. Thomson† has obtained a similar relation between secondary Röntgen radiation and atomic weight. With the exception of nickel an increase in atomic weight was always accompanied by an increase in the amount of secondary ionization.

In view of these interesting results, an attempt was made to derive a relation between primary Röntgen radiation and the atomic weight of the substance producing the rays. A special form of Röntgen bulb was employed, and the quantity of rays emitted was measured by an ionization method.

There were one or two things to be considered. Firstly, some of the substances it was proposed to use, have comparatively low melting points, and therefore it was not advisable to focus the cathode rays on the anticathode by using a concave cathode. A plane cathode was accordingly employed. Secondly, this being so, only a central pencil of the cathode rays should be used, so as to restrict them to the anticathode area.

It follows that the quantity of Röntgen rays produced, would never be very large, and might in unfavourable circumstances be small. So it was advisable to keep down the capacity of the ionization chamber system, and also to allow the emergent Röntgen rays to pass out of the bulb through as thin an aluminium window as would withstand the atmospheric pressure from without. Such a window would of course stop all the secondary cathode particles which are produced along with the Röntgen pulses when the primary cathode particles are arrested by the anticathode.

* McClelland, *Sci. Trans. Roy. Dublin Soc.*, 1905 and 1906.
† J. J. Thomson, *Proc. Camb. Phil. Soc.* xiv. 1, p. 109, Nov. 1906.

Arrangement of Apparatus.

The general arrangement is shown in figure 1, which is drawn to scale. The discharge tube *D*, containing the cathode and, in a side tube, the anode, was constricted over its lower half, where it met the anticathode tube *A*. The central beam of cathode rays met the anticathode at 45° and a pencil of the Röntgen rays produced, passed along the tube *B*, which was mounted at right angles to the discharge tube. These relative directions were chosen because they are the usual ones in ordinary X-ray practice.

Both the electrodes were of aluminium.

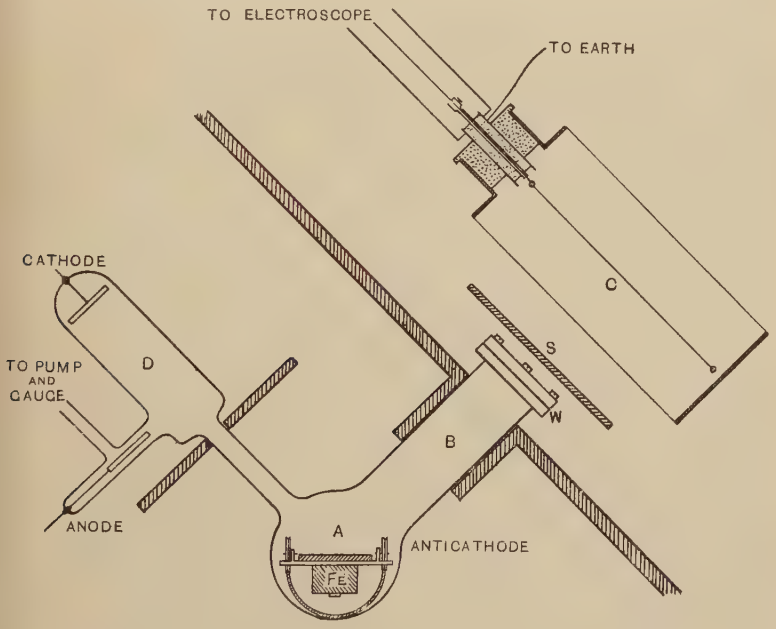


Fig. 1.

The metals used as anticathodes were mounted on a car which ran along horizontal rails fastened by sealing wax to the bottom of the tube *A*. For rails one half of a piece of aluminium tube, split from end to end, was used. The car was also made of aluminium and was arranged to carry some eight metal discs in line. These were of diameter 2·5 cms., thickness 2 mms., and were kept in position by small central pins, which passed through corresponding holes in the body of the car. The latter for convenience of space was slung from the axles of the wheels. Underneath each axle

was fastened a piece of soft iron, and by means of a small electromagnet outside, it proved very easy to move the car along the rails and bring any metal desired under the beam of cathode rays.

In every case the metal of the anticathode had its surface cleaned and polished. This was usually done first with the finest flour emery and finally with jeweller's rouge. The lead plate had its surface renewed by planing.

With the first batch of metals introduced, a small Willemite screen took the place of one of the metals. This was prepared by dusting finely crushed Willemite (natural silicate of zinc) on a small piece of glass plate previously moistened with a weak solution of water-glass (silicate of soda), and then drying over a small flame. Such a screen does not impair the vacuum by giving off gas when a discharge plays on it. The cathode rays, when they struck the screen, produced a bright green elliptical patch of phosphorescence, which served as a test of whether the rays would be truly directed on the anticathode metals which were in line with the screen on the car.

The whole anticathode system was earthed and joined outside by a wire to the anode. The discharge was generated by a 6-inch Apps Induction Coil. In parallel with the tube was an adjustable spark gap between two brass spheres 2·54 cms. in diameter. These were kept well cleaned and polished, and their distance apart for the first spark gave a rough measure of the mean potential difference between the terminals of the tube.

A Töpler pump was used to produce the vacua, and a McLeod gauge gave a measure of the pressures. With such a large mass of metal in the tube it was to be expected that a considerable quantity of gas would be evolved when the pressure was reduced, and indeed these expectations were not belied, for it took some weeks of pretty steady pumping with the discharge running before any readings could be taken. At one stage one could not keep pace with the evolution of gas, and it was difficult, with the discharge running, to get below a pressure in the neighbourhood of $\frac{1}{30}$ mm.

Such pressures are very favourable to cathodic disintegration, and aluminium deposits were in this way formed on the anticathode. It may be worth noting that the evolution of gas was hastened by reversing the discharge, and thus using the anticathode as cathode. The plan has moreover the advantage of splashing off on to the surrounding glass any cathodic deposit which may have been formed on the anticathode. The formation of these disintegration deposits, it was found, was almost if not entirely prevented by earthing the anticathode system and with it the anode.

At this point it is interesting to note the behaviour of the lead

disc which formed one of the metals of the anticathode. Villard* showed that cathode rays reduce an oxidised copper plate to metallic copper. In just the same way it was noticed that the lead disc, which had tarnished a little before the apparatus could be sealed and exhausted, gradually developed a bright elliptical patch of clean lead at the place where the pencil of cathode rays impinged.

As mentioned above, a portion of the Röntgen rays passed along tube B and out through the aluminium window W into the ionization chamber C. If a screen S was used to cut down the rays, it was inserted in front of the ionization chamber. The aluminium window was ·067 mm. thick and 2 cms. diameter, and perceptibly sagged under the outside pressure. It was not possible to cement such a sheet of metal directly to the thin edge of the glass tube, and be sure of a joint which would stand. To get over this, a brass tube which would just slip over the glass tube, was provided with a heavy flange. A stout ring was screwed down to this by six screws equally spaced. The aluminium sheet was gripped between the ring and the flange, and the joint was completed with sealing wax, the screws being tightened up while the sealing wax was still molten. The brass tube was then sealed to the glass tube, and this part of the apparatus gave no further trouble through leakage.

The whole of the discharge tube was surrounded with sheet lead through a hole in which the Röntgen ray tube B penetrated.

The ionization chamber consisted of a flat cylinder of brass about 4 cms. long and 9 cms. diameter. The faces were covered with aluminium leaf ·01 mm. thick. The front face was situated about 3 cms. from the aluminium window of the tube and was symmetrically placed with respect to it.

A ring of aluminium wire of diameter rather less than that of the cylinder was mounted with its plane parallel to and midway between the faces of the cylinder. Over the ring was fastened aluminium leaf and the whole was supported by a wire passing through and clamped in a tube insulated by a sulphur plug which was inserted in an earthed guard-tube. The guard-tube was insulated from the chamber by an ebonite stopper let into the side of the cylinder.

Aluminium leaf was chosen for the ends of the ionization chamber, partly because it is very transparent to Röntgen rays, and partly because it emits, as J. J. Thomson†, Townsend‡, and Barkla§ have shown, but little secondary Röntgen radiation, and

* Villard, *Journal de Physique*, 3me Série, VIII. p. 140, 1899.
† Thomson, *Proc. Camb. Phil. Soc.* XIV. p. 109, Nov. 1906.
‡ Townsend, *Ibid.* X. 1899, p. 217.
§ Barkla, *Phil. Mag.* [6] 7, p. 543, 1904.

that of a kind closely resembling the primary rays. It was, of course, essential to compare incident radiations by their direct ionizing effect, complicated as little as possible by any secondary radiation.

The electrical connections are shown in figure 2.

The outside of the ionization chamber was raised to a potential (200 volts) sufficient to give the saturation current for all the degrees of hardness of the Röntgen rays measured. The potential was supplied from a battery of small accumulators, with the negative pole earthed.

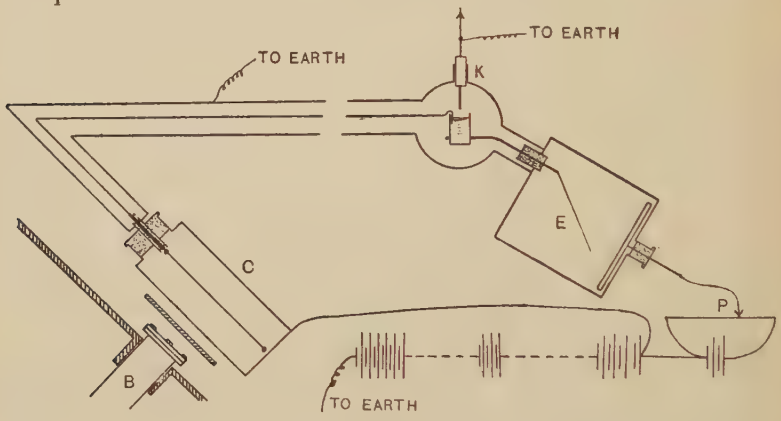


Fig. 2.

A Wilson tilted electroscope E was used to measure the leaks, and with its great range of sensitiveness, obtainable without the aid of any added capacity, proved extremely convenient for the purpose. If the electroscope was adjusted for great sensitiveness, a potential divider P, giving a control of $\frac{1}{50}$ volt, was used as a fine adjustment on the potential of the charged plate, which ordinarily was raised to something in the neighbourhood of 200 volts.

Indeed this potential divider proved to be a real convenience for all degrees of sensitiveness, and the zero of the electroscope, taken when the entire gold leaf system was earthed, could be kept perfectly constant. The movement of the gold leaf over a definite range was observed through a small telescope having a scale in the eye-piece. The times were taken with a stop watch.

A calcium chloride solution key K, which was operated from a distance, made or broke the earth connection. It is perhaps worth while laying stress on the advantages that a solution of metallic salt has over mercury for a key. The kick so common with mercury keys on making or breaking connection is quite prevented. The electrification produced by the splashing of solutions of salts is very small; for mercury it is large.

The insulation was of sulphur throughout. The electroscope was out of the path of, and well shielded by lead from stray Röntgen radiation. The connections of the ionization chamber to the electroscope were, as is usual, well shielded by earthed metal tubes.

Measurements.

In a comparison of the Röntgen rays, from two metals of the anticathode, electroscope readings were taken alternately a great many times—first using one metal and then the other. It is essential that the incident stream of cathode rays should remain steady and constant for a proper comparison. An induction-coil, such as was used, working with a hammer-break interrupter, cannot always be relied upon to run perfectly steadily and well for any length of time. It needs very careful adjustment of the current in the primary, of the hammer-break and its tension screw, to get good results for the particular pressure inside the tube. The surfaces of contact of the platinum break require attention from time to time—they should be kept clean and smooth and parallel. The amount of sparking at the hammer-break interrupter must be as small as it is possible to get it. When a coil is working well it emits a steady purr, unbroken by kicks and bumps at the break.

For steadiness of running, the current in the primary must be much smaller than that which would make the coil give its longest spark. In other words, the coil must run on a light load, and it is therefore better to use as big a coil as is convenient.

In spite of all precautions, only a small fraction of the readings actually taken were good enough to use. By comparing different pairs of metals, and thus getting a number of cross-checking results, an accuracy of 1 or 2 per cent. could probably be ensured for the final readings.

From time to time the pressure in the tube was read by the McLeod gauge, and a reading was taken of the length of the alternative spark gap. By taking a number of successive readings with the electroscope for the same anticathode, one could tell whether the coil were working well or not.

The usual length of a reading was from 20 to 50 seconds, and the coil was given two minutes rest between successive readings. This, of all the methods tried, was found to be the most satisfactory for yielding results which were concordant.

Results.

For the results given below a constant pressure of ·005 mm. of mercury was maintained in the tube, and the length of the alternative spark gap was ·8 cm., which is equivalent to a mean

potential difference of about 25,000 volts between the cathode and anode. Hence the Röntgen rays worked with were distinctly soft in character, and were largely cut down by quite thin sheets of metal. The aluminium window would let through all but the very softest rays.

The amounts of Röntgen radiation from the different metals were first compared when no additional screen was used to cut down the rays, so that they had only to penetrate the thin aluminium window to reach the ionization chamber. These relative values (calling platinum 100) are given in the third column of the table of results. No very evident relation is apparent between these numbers and the atomic weights of the anticathode metals, *e.g.* lead, silver and nickel, are all out of place. Perhaps this result is not altogether surprising when the heterogeneous character of the Röntgen rays is taken into account. It will be noticed that with the exception of aluminium, there is not a great deal of difference between the amounts of radiation from any of the other metals.

Atomic Weight	Anti-cathode	Relative Radiation						$\frac{R}{\text{At. wt.}}$
		No screen	Screen of					
			Al	Pt	Cu	Ni	Fe	
207	Pb	93	(R) 109	88	24	41	26	·53
195	Pt	**100**	**100**	**100**	24	41	25	·51
108 (154)	Ag	77	86	66	21	35	22	(·56)
64	Cu	87	35	29	**35**	33	12	·55
58·7	Ni	89	33	24	26	**33**	11	·56
56	Fe	83	30	19	6	29	**30**	·54
27	Al	20	14	9	3	9	5	·52

Screens of aluminium ·25 mm., ·5 mm., and 1 mm. thick were then inserted in turn in the path of the Röntgen rays. The first thickness of screen alters the relative amounts of radiation considerably, but very little further change is produced by thicker screens. Indeed the numbers for the ·5 mm. and the 1·0 mm. screens are almost identical.

In column 4 (under aluminium screen) is given a set of comparative values for the radiations (still keeping Pt = 100) from which the softest rays have been sifted out by an aluminium screen 1 mm. thick. Such a screen cut down the radiation from platinum about 35 times.

It is very evident that the radiation from an anticathode of low atomic weight, *e.g.* iron or nickel, is largely made up of rays that are very soft in character. Such metals have their relative radiation values largely reduced when the screen is used. On the other hand, metals of high atomic weight such as lead and silver have radiation values which are increased when we deal only with the harder type of Röntgen rays. These metals obviously give off a larger proportion of hard rays than the metals of less atomic weight.

The outcome is, that all the relative radiation values, for rays which have passed through an aluminium screen, now follow the order of the atomic weights of the anticathode metals; indeed the two exhibit an approximately linear relationship.

In the last column of all, the ratio of the radiation value to the atomic weight is given and, as will be seen, is roughly constant.

The case of silver must be mentioned. It amalgamated with the mercury vapour from the pump before any measurements could be made. It is hoped subsequently to make an analysis of the surface of the silver, but it is very probable that in the presence of a continual supply of mercury vapour the amalgam that silver forms is AgHg. The mean atomic weight of this is $\frac{108 + 200}{2} = 154$, and dividing this number into the radiation value for the silver, it will be seen that the quotient comes into agreement with the other values tabulated in the last column.

In the remaining columns are given the relative radiations which are transmitted through screens of platinum, copper, nickel and iron.

Consider the case of the platinum screen and compare the values with those obtained in the case of the aluminium screen. It was arranged that the radiation from the platinum anticathode should be cut down as much with the platinum screen as it was formerly by the aluminium screen, so that rays of equal hardness were employed. It will be noticed that again giving platinum the value 100, the values for all the other metals are considerably less than they were when the aluminium screen was used. The value for lead is now actually less than that for platinum, but with this exception, the order is undisturbed. Evidently a platinum screen shows a special transparency to Röntgen rays from a platinum anticathode. This abnormal transparency is shared in less degree

by rays from other metals—to an extent depending on the proximity of the atomic weight to that of platinum, *e.g.* lead and silver have their former values cut down by about 20 per cent., while nickel and aluminium are about 35 per cent. less than they were with the aluminium screen.

Now compare the column of values for the copper screen with those for the aluminium screen. For ease of comparison copper is given the value 35—the same as it had with the aluminium screen. It will be seen at once that there is evidence of marked selective transmission. A copper screen is now easily first in transparency; the next is nickel whose value exceeds those of silver, platinum and lead, although their atomic weights are much higher.

Similar results will be observed when the columns for nickel and iron screens are also compared with the column of values for the aluminium screen. Take the case of the iron screen, and compare it with the aluminium screen. Then giving the radiation from iron the same value 30 in each case, it will be seen that the new values for lead, platinum, and silver are about a quarter, and those for copper, nickel, and aluminium about a third of their values with an aluminium screen. This again indicates that the degree of transparency of a metal to Röntgen rays, is a function of the proximity of the atomic weight of the radiating metal to that of the screen.

It is worth noticing the big jump that occurs in the character of the radiation in passing from nickel to iron, and the resemblance between the radiation from nickel and from copper. For instance a nickel screen is more transparent to radiation from copper than to radiation from iron; a copper screen transmits radiation from nickel far better than radiation from iron, while a screen of iron transmits radiation from copper and from nickel almost equally badly. Barkla*, working with secondary Röntgen radiation, has noticed a similar resemblance between copper and nickel, and a corresponding jump between nickel and iron.

Yet it must be remembered that the atomic weight of nickel (58·7) is nearer the atomic weight of iron (56) than it is to that of copper (64). Nickel and iron show some chemical resemblances and are placed in the same group (VIII) of the Periodic Classification, copper being situated in group I. On the other hand, a point worthy of remark is that copper and nickel have densities which differ but little—8·95 and 8·8 respectively, while the density of iron is distinctly less—7·8. It would seem therefore that the density of the absorbing screen, rather than its atomic weight is the important factor in this screening effect.

* Barkla, *Nature*, Feb. 14, 1907.

Conclusions.

The results indicate that a metal screen is specially transparent to Röntgen radiation from an anticathode of that metal, and that this abnormal transparency is shared in less degree by metals with atomic weights differing little from that of the anticathode.

The effect seems to point to the view that the Röntgen rays emerging from the interior of the anticathode to the surface undergo selective absorption, leaving the remainder specially penetrating to further layers of the same substance and to a less extent to substances of neighbouring atomic weights.

Using a plate of aluminium as the absorber, the amount of transmitted radiation was found to be approximately proportional to the atomic weight of the metal used as anticathode over a wide range of atomic weights.

It may be that this selective absorption is a maximum for one particular degree of hardness of X-rays depending on the metal, and that a metal of high atomic weight shows selective absorption for a harder type of Röntgen ray than that which gives the effect for a metal of smaller atomic weight.

The experiments are being continued.

I should like to thank Prof. Thomson for some helpful suggestions, and for his interest in the investigation, which was carried out in the Cavendish Laboratory.

Parasitic Trees in Southern India. By C. A. Barber, M.A., F.L.S., Christ's College, Cambridge. Government Botanist, Madras Presidency. (Communicated by Professor Seward.)

[*Read* 20 May 1907.]

1. Although it has long been known that *Santalum album*, the sandal tree of commerce, is a root-parasite, yet those in charge of sandal plantations in India have, until recently, been remarkably oblivious of the fact.

This is not to be altogether wondered at when we look at the trees themselves. There is nothing in habit, foliage or size to suggest anything out of the ordinary. Well clothed with light green leaves and bearing masses of flowers and fruit, a height of 30 to 40 feet is not infrequent with a girth of 2 to 3 feet at the base. Kad Handi, an intelligent observer of the tree, refers to a giant sandal eight feet in girth and producing $1\frac{1}{8}$ tons of excellent heartwood. Although from the commercial point of view the sandal matures at an age of 30 to 50 years, its total length of life not infrequently reaches double that period. It is quite unexpected even to the trained student of plant life that such trees should prove to be hemi-parasites, with few or no root-hairs and almost entirely dependent for their water and mineral salts upon the roots of their neighbours.

The natural zone of the sandal tree is fairly circumscribed, an irregular area in the native state of Mysore, with a few less important outliers in the Madras Presidency, coinciding roughly with the southernmost ending of the great Deccan plateau of the Indian Peninsula. The requirements of the sandal are given by authorities as an equable climate with a rainfall of about 40 inches and a mean temperature of 74° F.

Sandalwood is a state monopoly in Mysore, which produces the great bulk of it, and the forest revenue of this state is largely derived from this product. Anyone convicted of injuring the trees is liable to severe penalties. This is exemplified by the following extract from the Mysore forest laws. "Any occupant or holder of land who fails to report at once in writing to the...(nearest official)...the fact of injury, arising from whatever cause, to any sandalwood tree or trees growing upon his land, shall be liable, upon conviction before a competent magistrate, to a fine which

may extend to Rs. 200." This sum is a very large one in the eyes of the native cultivator. In more barbarous times the penalty was frequently "a limb for a limb," a leg or arm being cut off for wounding sandal trees, and on repeated offences the head being removed.

This state monopoly brings in something like £50,000 a year. The machinery for collecting the wood is very simple. The country is divided up into districts with so-called "depôts" at intervals. The dead trees (equally valuable with the living from the oil-producing point of view) are collected each year, until a certain specified quantity has been brought together, the rest being allowed to lie till the following year. The logs are pared of young wood and the cleaned heartwood is cut into billets of various sizes, and these are classified according to a complicated terminology. Annual auctions are held in the depôts, when buyers come from all parts of India.

During the past 30 years continued efforts have been made to increase the natural forests of sandal by *artificial plantations*. These have, as a rule, been unsuccessful, but have incidentally led to a more careful study of the plant. Under suitable conditions of soil and temperature, rainfall and elevation, the sandal has been found to succeed best when planted with certain other plants which have earned the name of "nurses." The relations between the sandal and its nurse have been exhaustively discussed. It has usually been assumed that the shading of the soil and lower parts of the stem by the nurse was of advantage, while it was found that the plant did not thrive unless its head was free in the sun. This would of course be expected when considering its usual habitat—the outskirts of forests, scattered through low scrub or in hedges. The seeds are heavy and are scattered by birds in thickets, and the young plants, unless growing under cover, are greedily eaten by deer and cattle. The general results of this study of nurses have been summarised by one of the principal forest officers as follows: "Sandal should not be planted pure, but with some good shade-giving species, (1) because it is a shade-lover and a lover of more shade than is given by its own foliage, (2) it flourishes best in a vegetable soil which its own foliage is not capable of producing, (3) it requires shelter when young, and (4) *there is the doubtful question of root parasitism.*" This latter clause is one of the few references to the parasitic nature of the sandal in the forest literature of the subject.

Where the neighbouring vegetation has died out and the sandal is left standing, it frequently becomes unhealthy and, after lingering for a time, also dies. It is usual then to deplore the absence of lateral shade and to speak of "sun-scorch." But all these facts are readily explained by the knowledge that the tree is a root-

parasite. It needs the roots of other plants for its nutrition and growth, and their presence for its protection against the attacks of animals, and when it is isolated, its food supply is cut off and it becomes hide-bound, starved and moribund.

Recently a very serious and obscure disease has appeared in the sandal tracts. This has been called "spike," and will be referred to here briefly because of a useful opening for a young student of plant pathology. The government of Mysore, alarmed at the ravages of the disease, have offered a prize of Rs.5000 (£333) for the discovery of the cause of the disease and its control within one year. While a clear exposure of the causes leading to spike would be of the greatest value to the government of Mysore, the clause demanding a cure within one year shows little grasp of the difficulty of the problem and, as it is likely to defeat the object aimed at, should be removed.

The sandal is a beautiful tree with feathery foliage of bright green leaves and covered with small brown flowers. The first indication of spike is the diminution in size of the leaves, their appearance thus becoming more feathery, and the cessation of flowering. A flower terminates each branchlet and its formation gives the shoot a rest from leaf-formation until the fruit ripens. In spiked trees the branch grows on without cessation, forming smaller and smaller leaves of short duration until a small tuft is left at the end of each twig (Plate I.). This latter appearance is responsible for the term "spike." This change of the foliage into the "small-leaf" condition, not uncommon in tropical plant-diseases, is accompanied by the death of all the root-ends—the *haustoria*. An examination of the tissues under the microscope shows these to be charged with masses of starch, which fill every available cell, even to the thyloses in the vessels of the roots. Evidently, while abundant starch is formed by the leaves, there is a complete stagnation in metabolism. In a very short time the tree dies completely.

This disease at first attacked very old trees, and the collection of the required quantity of wood was rendered rather easier than otherwise, and little was done by the government to stay its progress. Now that it has spread to very young trees and no seed is being formed, the sandal tree has disappeared altogether from certain tracts. In other districts, while the immediate supply is not diminished, there are comparatively few young trees coming on to replace the dead ones. It is satisfactory to see that the Mysore government has at length taken a step in the direction urged on them years ago.

The present study of root-parasites in India may be traced directly to the occurrence of this disease. The writer was deputed for a few days to investigate the matter, and it was soon demon-

strated that the sandal was largely if not entirely a root-parasite, and it was noted with surprise that the haustoria on the roots had never been described.

2. A table is appended of the classification of the *Santalaceae* and *Olacaceae* as contained in Bentham and Hooker's *Genera Plantarum*. The plants *italicized* have now been demonstrated to be root-parasites. Only a few of the genera which are not known to be parasites are inserted.

Polypetalae.
Disciflorae.
Olacaceae.

(1) Olaceae	(2) Opilieae	(3) Icacineae	(4) Phytocreneae
Olax	*Cansjera*	Gomphandra	Phytocrene
Ximenia	*Opilia*	Apodytes	Iodes
Strombosia			Natsiatum
Erythropalum			

Monochlamydeae.
Santalaceae.

(1) Thesieae	(2) Osyrideae	(3) Anthoboleae	(4) Grubbieae
Quinchamalium	*Comandra*	Exocarpus	Grubbia
Arjona	*Santalum*	Champereia	
Thesium	*Buckleya*		
Thesidium	*Osyris*		
	Henslowia		
	Phacellaria		
	Myzodendron		

There is little doubt that the list of parasitic plants in these two orders might easily be extended by observing them in their natural haunts.

The fact that plants with green leaves might be parasitic with their underground roots (as contrasted with epiphytic parasites such as the Loranthaceae) was first demonstrated by Mitten in 1847 in *Thesium humifusum*. This was immediately followed by Decaisne in various small *Rhinanthaceae* which he found it difficult to transplant from nature to his botanical garden. In 1858 Planchon noted the parasitism of *Osyris alba* and, in 1871, Scott in Calcutta, finding it difficult to move *Santalum album* without a very large ball of earth, hit upon the idea of its being attached to the roots of other plants. In 1897, lastly, Shirai discovered the parasitism of *Buckleya Quadriala* in Japan, and the haustoria have been described by Kusano. It is to be noted that these discoveries were largely independent of one another and, so to speak, by chance, indicating how little we can really learn of plant life by the ordinary work of the systematist—in herbaria.

So much for the *Santalaceae*. Root-parasitism may now be extended to a series of tropical shrubs and climbers among the *Olacaceae*, in general appearance even less suggestive of this peculiar habit than the sandal. A preliminary study has revealed the fact that at least four genera are thus provided with the capacity of obtaining their mineral salts and water from the roots of other plants. The first observation of root-parasitism among the *Olacaceae* was not, however, made in India, but by Heckel in some seedlings of *Ximenia americana* raised in the botanical garden of Marseilles. The work in South India was quite independent of this. My botanical assistant in Madras, having been sent out to collect sandal haustoria, in his digging came across some so different in appearance that he traced them to their parent which proved to be *Cansjera Rheedii*. Again, independently of this, the author found haustoria on the roots of *Olax scandens*. This has led to a study of the *Olacaceae* in Madras whenever opportunity occurred, and collections have already been made of haustoria in the roots of *Cansjera Rheedii*, *Olax scandens*, *Ximenia americana* and *Opilia amentacea*. Further examination will undoubtedly increase the number of genera and species, at any rate among the *Olaceae* and *Opilieae*.

I may remark, in passing, on the laborious and even dangerous nature of this collecting work. The ground has usually to be broken up by crowbars unless carefully watered for days before—a matter of great difficulty in these dry regions—and it is extremely difficult to get the haustoria out uninjured, while the tracing of the roots attached to their proper species, which is essential, is very laborious. In one case a root of sandal was followed for two days at a depth of from one to three feet, extending to a distance of 105 feet in an almost straight line. No living endings were found in this space, a fact which indicates to what a distance these parasitic plants can travel underground in search of the roots of their hosts.

The country in which *Ximenia* and *Opilia* are found is, furthermore, very feverish. The two officers deputed to examine these plants in September last have been constantly ill since that time to the present date, while the servant who accompanied them died of the effects of the journey.

The Natural Order *Olacaceae* has been fittingly regarded as a refuge for the destitute, a sort of botanical rubbish heap on which various plants with a certain superficial resemblance might be dumped. The four sections of the order have little in common when closely examined. To give an idea of the uncertainty regarding different genera, let us take *Cansjera* which, according to van Tieghem*, has been treated as follows:—

* Van Tieghem, "Recherches sur la structure et les affinités des *Thymeleacees* et des *Peneacees*," *Ann. d. Sc. Nat.* Sér. VII. T. XVII. 1893.

(1) A. L. de Jussieu in 1789 placed it among the *Thymeleaceae* and was followed in this by Endlicher in 1840.

(2) Bentham in 1841 introduced it to *Opilieae* and was supported by Decaisne in 1843, Griffiths in 1844 and Endlicher in 1847.

(3) Miers in 1851 replaced it under *Thymeleaceae* and Meissner followed him in 1857.

(4) In 1867 Bentham and Hooker placed it among the *Opilieae*, and were supported by Engler in 1889.

(5) Baillon in 1892 placed the genus among the *Loranthaceae* while, as we shall see, van Tieghem in 1893, referring it to *Opilieae* again, removed that sub-order from the *Olacaceae* and placed it near *Santalaceae* among the Monochlamydeae.

There can, obviously, be nothing very determining in the floral characters of *Cansjera* and of the *Olacaceae* generally, and several workers have been busy studying the anatomy of the various genera and species of the order from the systematic point of view. Valeton*, Edelhoff† and van Tieghem have noted the structure of the stems and leaves in a considerable number of species. Their results suggest the separation of the four groups of the *Olacaceae* from one another. The occurrence of haustoria among both the *Opilieae* and *Olaceae* appears to show a connection between these two, but the structure of these organs shows that the *Opilieae* are much nearer the *Santalaceae* than to the *Olaceae*, a result in full agreement with van Tieghem's conclusions.

3. The haustoria of *Santalum album* have now been thoroughly studied and are described in the Memoirs of the Department of Agriculture in India‡. The following summary is given here regarding the internal structure. These organs appear in nature as rounded or conical outgrowths of the roots, fixed with their broad bases on to the roots of the host, and vary in size from a pin's head to a hazel nut. They are closely applied to and more or less envelope the roots attacked. In the earlier stages the haustoria are not infrequently free or attached to pebbles, bits of sticks or other unprofitable substances, but no great development takes place unless a foreign root is encountered.

In such early stages a certain amount of differentiation is already discernible. In a section through the length of the haustorium, the mother root and the vascular strand coming from it (the transitional region) may be distinguished from the haustorium proper. The latter again is divided into nuclear and cortical

* Valeton, *Crit. Overz. d. Olacineen*, Gröningen, 1886.

† Edelhoff, "Vergl. Anat. d. Blätter der *Olacineen*," *Engler. Bot. Jahrb.* Bd VIII. 1887.

‡ Barber, "The Haustorium of Santalum album," *Mem. Dep. Agr. India*, Nos. 1 and 2, where also see Literature.

portions. The nucleus appears as an oval mass of smaller, denser, more protoplasmic cells at the distal end of the organ, where it applies itself to the body attacked. On either side of the nucleus, larger, more permanent parenchymatous cells form the cortex. The latter is produced on either side of the foreign body so as to clasp it in the form of two cortical folds.

As growth proceeds, the median part of the nucleus, becoming denser, developes into a well-defined gland (Plate II., fig. 1), with lumen and duct. The purpose of the gland is presumably the outpouring of a dissolving secretion and, from observation of the tissues attacked, this secretion appears to be mainly cyto-hydrolytic, starch grains being in many cases more slowly dissolved than the cell walls. An examination of the glandular cells shows that the secretion is formed beneath the cuticle, and, in good sections, a series of parallel curved lines (ghosts) show that successive outpourings have occurred in each cell of the mucilaginous substance which fills the lumen of the gland. The secreting cells bordering the lumen form a well-marked epithelium-like layer, in which the dense protoplasmic contents collect in the lower half of the cell cavity, the upper part being full of clear substance (Plate II., fig. 1 a).

When the haustorium meets with a substance difficult to penetrate, a fresh mass of meristematic tissue is frequently formed at the point of contact, which developes a fresh nucleus and fresh cortical folds. The latter grow down on each side between the part clasped and the earlier folds, thus detaching them and taking their place. Compound haustoria are thus formed, which present the appearance of a series of haustoria one on top of another, the latest formed one alone being in contact with the foreign body. Such compound haustoria are formed, especially when the root encountered has thick bark or strong sclerotic protective bands, such as characterise the roots of tropical *Leguminosae*, and those of palms, bamboos, &c. The compound haustorium may therefore be regarded as indicating a series of successive efforts at penetration. Compound haustoria have been met with attached to pebbles and, in one case, to the chrysalis of a minute Lepidopteron. One haustorium was observed which had made five separate attempts to penetrate a refractory particle of quartz. The haustoria are freely developed when no other roots are present and this, together with the facts just noted, shows that no definite organic stimulus is necessary for their formation.

There is considerable internal pressure in growing haustoria. This is caused by the great increase in size of the organs, their close contact with the root attacked and the resistance of the surrounding particles of soil. This pressure is indicated by the appearance, at an early stage of development, of a band of

collapsed cells in the cortex on either side of the nucleus (Plate II., fig. 1, the dotted lines). These bands form separation layers in that the cells on the two sides of each speedily acquire different characters as regards their arrangement and contents, the outer layers becoming early permanent and, later on, moribund. The collapsed layers extend, in the sandal, from the end of each cortical fold, towards the base of the haustorium as far as the point where the haustorium proper joins the transitional region (Plate III., fig. 7, *cl*).

When entrance has been effected, a portion of the haustorium, the sucker, is thrust into the root attacked in the form of a tongue-like protrusion. This entering process remains simple in monocotyledon roots or in soft substances. But in dicotyledon roots with a firm woody cylinder, the sucker, unable to penetrate the denser lignified tissues, passes on either side along the line of the cambium, as two broad lobes or lamellae. The cambium is destroyed as the sucker lobes pass along it, and the formation of secondary wood in the host's root ceases at the invaded portion. After entering, the sucker swells greatly in thickness and the bark and cortex of the attacked root are thrust back as cortical wings until they are more or less parallel (Plate III., fig. 7).

Shortly after the sucker has reached the woody cylinder of the host, two broad parallel bands of vessels appear in it, separated by a parenchymatous "pith." The ends of these bands apply themselves, as isolated rows of vessels, to different parts of the xylem of the host. As these vascular elements are connected with those of the transitional region, continuity is thus attained between the vessels of host and parasite. Cambium is present on the outer edge of each band of vessels but phloëm elements are not met with, the latter being only found in the mother root and the vascular branch from it in the transitional region. The course taken by the vascular strand in the haustorium is characteristic, and may be followed on fig. 7 of Plate III. Passing downwards from the mother root, the vessels, at first forming a compact strand, separate widely in the transitional region. Below this they approach one another again, thus forming a wide loop, and pass to the two parallel bands of the haustorial axis already mentioned. At the point of junction of the transitional region and the haustorium proper, that is, just above the widest part of the loop, a curious change soon takes place in the vessels, in that they become disorganised, lose their markings and become filled with a yellowish mucilaginous mass. This point in the vascular system may be appropriately called the "interrupted zone." Secondary thickening takes place to a moderate extent in sandal haustoria.

Such is, in brief, the history of the development of the haustorium of *Santalum album*, and for fuller details the reader must be

referred to the Memoirs already mentioned. In the series of diagrams on Plate III., the haustoria of *Santalum album*, *Thesium Wightianum*, *Buckleya Quadriala* from Japan as figured by Kusano, *Osyris arborea*, *Opilia amentacea*, *Cansjera Rheedii*, *Olax scandens* and *Ximenia americana* are figured, all having successfully penetrated dicotyledon roots in a perfectly normal manner. The main points to be noted in these diagrams are the vascular system and the collapsed layers, the latter offering important evidence regarding the changes which have taken place in the arrangement of the tissues during development. The study of the haustoria, with the exception of *Santalum* and *Olax*, is at present very incomplete. In all cases (excepting of course *Buckleya*, the Japanese form, which I have not seen) a well-defined gland has been observed (Plate II.), and this gland differs more or less in form and development in the various genera. It is a somewhat remarkable fact that these organs have not been as yet described in any haustorium of this class.

With such materials as are at present available, the following appear to be the main characters of the haustoria of *Santalaceae* and *Olacaceae* collected in South India.

In *Santalum album*, *Osyris arborea* and *Thesium Wightianum*, compound haustoria are common: calcium oxalate crystals are found: the collapsed layers terminate upwards opposite to the interrupted zone and are of simple origin: a well-developed schizogenous gland is frequently present before penetration, and the secretion is subcuticular in the part of the cell directed towards the lumen of the gland; there is a distinct interrupted zone in the vascular system: the sucker is composed of nucleus with cortex.

Cansjera Rheedii and *Opilia amentacea* also have compound haustoria: there are no crystals of calcium oxalate, their place being taken by cystoliths with crystalline plates of calcium carbonate: the collapsed layers end as in *Santalum*: a gland is present and, although it has not been studied sufficiently as yet, it appears to resemble that of *Santalum* and is simple in structure: the interrupted zone is a very marked character in these species.

In *Olax scandens* the haustoria, which have been thoroughly studied, present remarkable differences from all the preceding. They are never compound: calcium oxalate crystals are abundant: the collapsed layers are formed of three separate parts and terminate generally far below those already described, passing inwards under the vascular loop. This arrangement of the collapsed layers indicates considerable differences in development: there is a highly complicated gland which is lysigenous, the lumen being filled by parallel rows of cells in various stages of disintegration: below the fully developed gland on either side a remarkable clear

tissue is developed in the centre, which may be of the nature of a water reservoir: there is no trace of the interrupted zone in the vascular system: there is a single, median plate of vessels instead of two parallel ones, and there is consequently no pith in the axis of the haustorium: the sucker consists entirely of nuclear tissue (cf. Plates II. figs. 6 and 6 a, and III. fig. 13).

Ximenia americana agrees in certain respects with *Olax scandens* but differs in others. It has not as yet been sufficiently studied. Calcium oxalate crystals are present: the collapsed layers end as in *Olax*; there are two bands of vessels in the axis of the haustorium: there are indications of the clear tissue as in *Olax*: the cortical folds completely envelope the root attacked and the haustoria attain to a very large size, reaching a square inch in surface area in the specimens collected (cf. Plates II. figs. 5 and 5a, and III. fig. 14).

The study of the haustoria of *Santalum album* and *Olax scandens* is completed and will be published in due course. That of the remaining species collected in South India is proceeding.

Description of Plates.

Plate I. A small branch of *Santalum album* with the first appearance of "spike." The middle twig is normal and, as it is fruiting, it is resting from leaf-formation. The side branches, at first normal, are passing into the small-leaf condition. It is easy to mark the exact spot where the spiked condition has commenced. Not only are the leaves smaller but they are much closer together and the internodes are shorter. From the latter character it is always easy to tell when a tree has died of spike.

Plate II. Diagrams of the haustorial glands of (1) *Santalum album*, (2) *Osyris arborea*, (3) *Thesium Wightianum*, (4) *Opilia amentacea*, (5) *Ximenia americana*, and (6) *Olax scandens*.

The first four are more or less similar and the lumen in young glands, as shown in 1 a, is traversed by the faint outlines of the upper part of the secreting cells.

In 5 and 6 the fate of the secreting cells is different and the lumen, in very young glands (5 a and 6 a), is traversed by rows of cells which are becoming disintegrated and, ultimately, disappear entirely. The two latter, members of the *Olaceae*, thus differ from the *Santalaceae* (1—3), and *Opilieae* (4) in that the glands are schizogenous instead of lysigenous.

The double lines on Plate II represent the surface of the root attacked, the gland being always formed close to it. The dotted line marks the place where the collapsed layers are beginning to appear. It will be noted that here too the *Olaceae* differ from the rest.

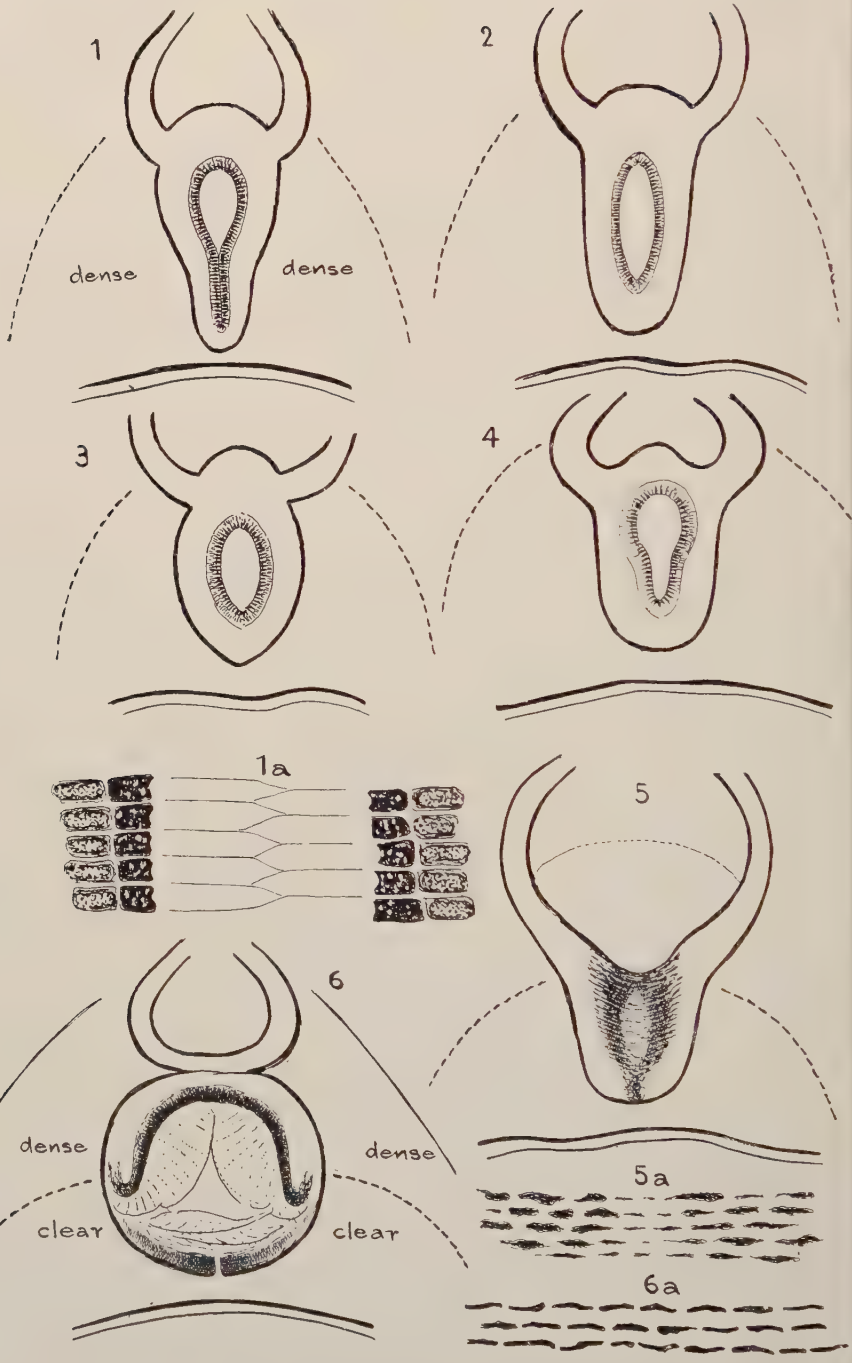
Lastly, comparing 1 and 6 as representatives of the two classes of haustoria, the cells near the root attacked are clear of contents in *Olaceae* and dense or full of starch and protoplasm in all the others.

Plate III. Diagrams of various mature haustoria in *Santalaceae* and *Olacaceae*. 7, *Santalum album*. 8, *Thesium Wightianum*. 9, *Buckleya Quadriala*, after Kusano. 10, *Osyris arborea*. 11, *Opilia amentacea*. 12, *Cansjera Rheedii*. 13, *Olax scandens*. 14, *Ximenia americana*.

In all cases the root attacked and split open is surrounded by the broad dark line. Of the haustorial tissues only the collapsed layers, *cl*, and the vascular tissue are shown.

The upward ending of the collapsed layers is characteristic. This is opposite to the broadest part of the vascular loop in *Santalaceae* and *Opilieae* (7—12), but much lower in *Olaceae* (13 and 14: see also 5 and 6 on Plate II). The interrupted zone of the vascular tract is very distinct in the *Santalaceae* and *Opilieae*, but is apparently absent in *Olax* and *Ximenia*.

The structure and development of the haustoria of *Opilieae* resembles that of *Santalaceae* far more than that of *Olaceae*.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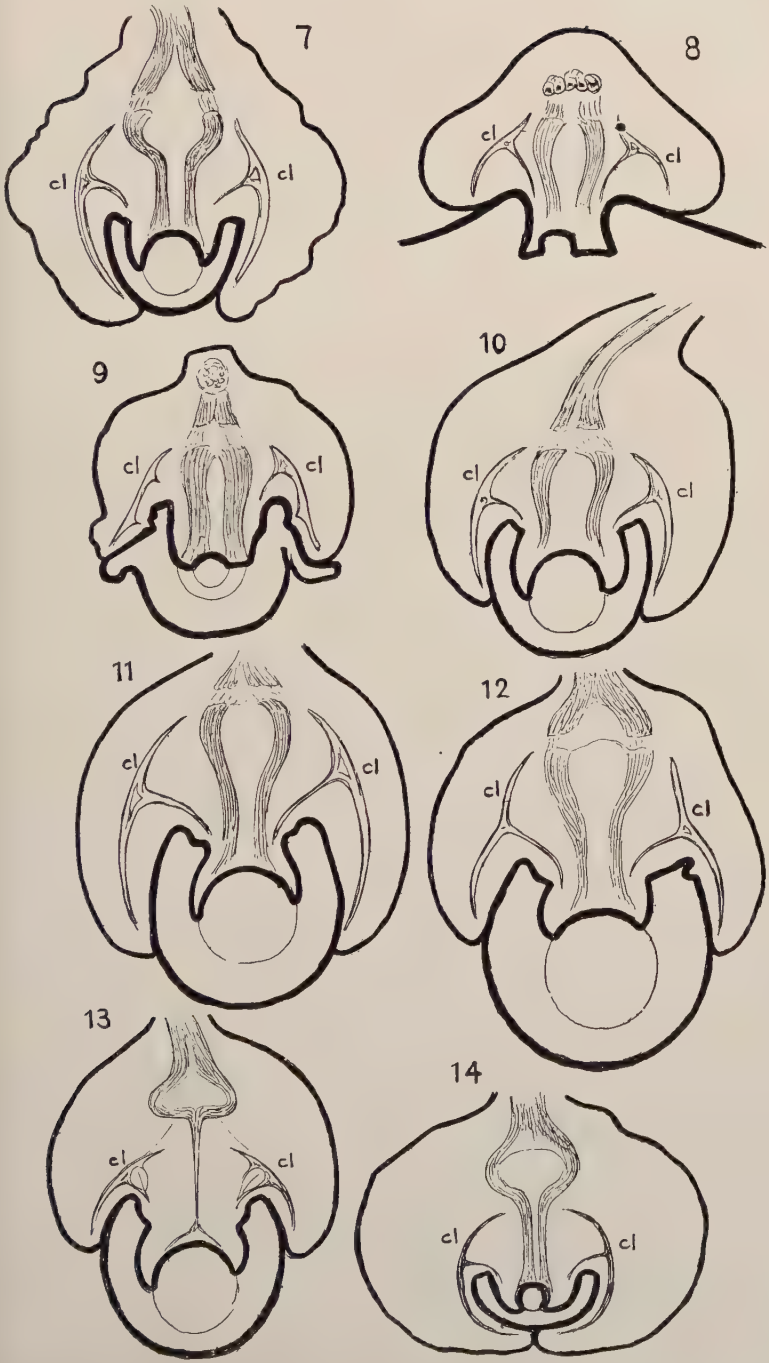
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On the Longitudinal Impact of Metal Rods with rounded ends. By J. E. Sears, B.A., St John's College. (Communicated by Professor Hopkinson.)

[*Read* 6 May 1907.]

The object of the present paper is to compare the velocities of propagation of elastic waves in metal rods, as determined by a certain dynamical method, with those obtained by the ordinary static method, using the formula $v = \sqrt{\frac{Eg}{\rho}}$.

Experiments by Prof. Hopkinson* on the momentary extension produced in a long wire by a blow at one end proved that the observed and calculated velocities were the same within 2 or 3 °/₀ in a steel or iron wire, but in a copper wire the observed velocity came out about 5 °/₀ too high. It appeared probable that the latter difference was more than experimental errors could account for and it was suggested that it might be due to a time-lag between the strain and the stress producing it, which would cause the elasticity for stresses applied for a very short time to exceed that determined statically in a testing machine. In such a case the velocity of wave propagation would be higher than that calculated from the formula. The experiments here described prove, however, that the two velocities agree within one-half per cent. not only in steel and iron but also in copper and aluminium. This result is in remarkable contrast with that of Wertheim†, who, attacking the same problem in a somewhat different manner, almost always found discrepancies between the two methods, far too great to be accounted for by any heat effects in the metal.

The velocities of propagation in my experiments were determined by means of observations on the duration of longitudinal impact between pairs of equal rods of the metal. According to St Venant's theory, this should be equal to the time taken by a wave to travel twice the length of either rod. It was known, however, from the experiments of Voigt‡ and others, that the observed times would be longer than this by an amount depending on the nature of the surfaces at the point of impact; but it was hoped that this "end-effect" would prove independent of the length of the rods, provided the velocity and other conditions of the impact were kept unchanged. This was found to be the case, so that, by plotting duration of impact against length of rods, a straight line was obtained, whose slope gave the required value of the wave-velocity.

* "On the Effects of Momentary Stresses in Metals," *Proc. Roy. Soc.* Vol. 74.
† *Ann. de Chim. et de Phys.* 3e Sér., Tome 12.
‡ *Wied. Ann.* 19, 1883.

In order that the nature of the impact should not be materially affected by slight deviations from axial collinearity, the rods were made slightly convex at the ends where the impact took place. One most important effect of this is to render the duration and other circumstances of the impact, directly calculable from known data, the indefinite "Zwischenschicht" of Voigt's theory being replaced by a region of separation between the two rods, the mechanical properties of which depend only on the shape of their ends, and on the elastic constants of the metal. The law connecting stress and strain (or rather, total pressure and compression) in this region is, however, no longer linear, so that St Venant's method cannot now be adapted (as in Voigt's theory) to suit the requirements of the case. In the immediate neighbourhood of the point of contact, the relation between pressure and compression may be determined by the method of Hertz, but Hertz's theory of impact is inapplicable to the case of long rods, since it takes no account of any wave-motion which may be set up. But my experiments clearly prove that wave-motion is the determining factor of the impact, and that the waves are propagated with the velocity $\sqrt{\frac{Eg}{\rho}}$ given by St Venant's theory. This theory, then, must evidently form the basis of the required solution. The method must, however, be modified by the aid of Hertz's theory in order to deduce the effects of the rounded ends. I have succeeded in effecting the required combination of the two theories—with good results so far as I have been able to test them; but the solution is not given here as I wish to check it further before publication.

The times of impact were determined by the method first introduced by Pouillet*, and afterwards applied to the same problem by Schneebeli†, Hausmaninger‡, and Hamburger§. The experiments of the latter are particularly interesting as tending to confirm, in a general way, the results given in this paper with regard to a straight line law; but (as he himself remarks) the differences he obtains are much too small for St Venant's theory, whilst all his times appear to be very large. This does not seem easy to explain, but probably much greater accuracy is obtainable with modern instruments than was then possible. Hamburger's method of calibration, in particular, seems to offer considerable difficulties.

The method, as ordinarily employed in my experiments, consists in allowing an electric circuit to be completed by the contact between the two rods, the total quantity of electricity which passes,

* *Pogg. Ann.* 64, 1845.
† *Ibid.* 143—145, 1871–2.
‡ *Wiener Sitzungsberichte*, 88, 2te Abth. 1883.
§ *Wied. Ann.* 28, 1886.

from the time when they first meet until they again separate, being measured on a ballistic galvanometer. Neglecting, for the present, the corrections due to self-induction, we get the formula :—

$$q = \frac{V}{R_1} T, \text{ or } T = \frac{R_1}{V} q \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where q is the quantity of electricity; V the voltage; R_1 the resistance; and T the time of impact. The general arrangement of the circuit is shown in Fig. 1. The galvanometer G was

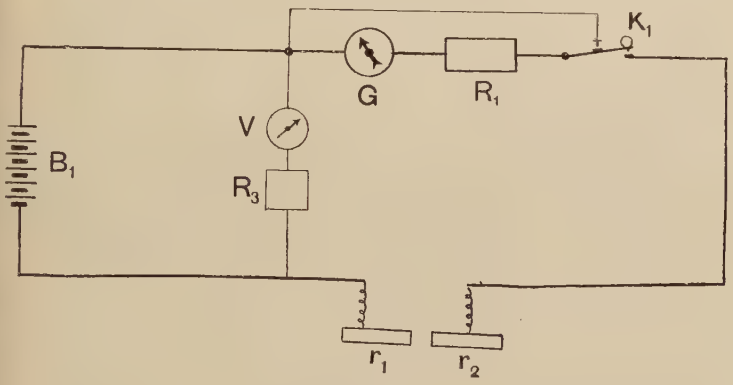


Fig. 1.

an instrument of the Ayrton-Mather form, by R. W. Paul, and had a coil of 600 turns (but of small self-induction) carried on a phosphor-bronze suspension. It was calibrated by placing it in circuit with a standard condenser and charging to a known voltage. This is the only method of calibration in which the galvanometer works under the same conditions as in testing the rods—i.e. making its fling on open circuit. Several attempts were made to check this calibration by the steady deflexion method, but were all frustrated by fatigue effects in the suspension when under the action of steady currents. The same voltmeter, V (a Siemens milli-volt-ammeter with variable series resistance), was used both in calibrating the galvanometer and in the actual testing of the rods. It was used in the same part of its scale for both purposes, so that no errors can arise from this source. In order that the varying contact-resistance between the rods, r_1, r_2, might be safely neglected, and also with a view to diminishing self-induction effects, the whole resistance of the circuit was made up to 5,000 ohms by means of the box R_1.

The corrections for self-induction are two in number :—

(a) The current, instead of rising instantaneously to its full value when the rods meet, grows exponentially.

(*b*) When the rods separate, a spark may be produced, so that the current does not fall instantaneously to zero.

With the high resistance and small self-induction used, the latter effect was found to be negligible, while the correction for the former was quite small ($2{\cdot}5 \times 10^{-6}$ secs.). The method of determining these corrections, together with other details of the experimental work, is fully described at the end of the paper.

The rods used were all $\frac{1}{2}''$ in diameter, the radius of the spherical ends being $1''$. It was only possible to obtain concordant results when these ends were kept scrupulously clean, the presence of the least trace of grease or dirt producing great variations in the readings. The spherical surfaces were therefore washed, first with KHO, and then with water, and carefully dried. They were then polished with a clean piece of fine emery paper (No. 0000). This process was then repeated, and sometimes it was even found necessary to repeat it a third time before satisfactory readings could be obtained. The rods were suspended from two parallel wooden beams by means of "V"s of fine cord (fishing line), being thus compelled to swing always in the same plane, and with their axes always horizontal (Fig. 2). In their

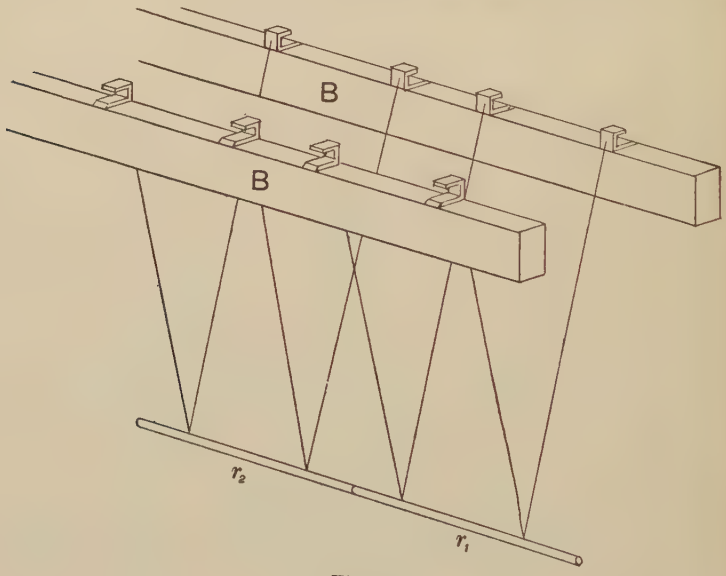


Fig. 2.

lowest position, the rods were collinear, and just in contact at their ends. The radius of the arc which they described was $5'$. Several preliminary experiments were made, first with three rods in line,

and then by allowing single rods of different lengths to impinge on the plane face of a large block of cast iron which was intended to represent an infinite solid. The straight line law now became apparent, but broke down when the rods became too long, owing to the reflected waves in the block coming into play. It was this which gave the hint to use the rods in pairs. It is, of course, impossible to imitate an infinite solid exactly; but if we allow two equal similar bodies to impinge symmetrically on each other, the effect on either is (by the very symmetry of the case) the same as if it had struck an absolutely rigid plane; and the case of an absolutely rigid plane is even simpler than that of the infinite (elastic) solid. The duration of the impact will, of course, depend only on the *relative* velocity of the two bodies, and in the actual experiments one rod was allowed to hang freely at rest, the other impinging upon it. The impact was regulated by first withdrawing the second rod to a distance which could be measured by means of a telescope mounted on a horizontal travelling screw, and then allowing it to fall freely. After some experiments a mechanical release was devised which effected this most satisfactorily, and which, when once adjusted, enabled the same withdrawal to be repeated rapidly without reference to the telescope.

A great many experiments had to be made before the apparatus was got to work satisfactorily, and the necessary corrections determined. These preliminary experiments were all made with steel rods, and with a withdrawal of 8″ (corresponding to a velocity of impact of about 20″ per sec.). When they were completed it was found that all the rods had become overstrained at the point of impact, so that the curvature there was slightly diminished. It was easy to detect this by observing the reflexion of a straight line in the polished surfaces of the ends, when a slight kink at once became apparent at the centre. The result of this flattening of the ends of the rods was to produce a diminution in the end-effect; but, as the different pairs of rods had received greatly different treatment, this diminution was not the same in all cases. It was therefore necessary to re-turn and polish the ends, and to repeat all the experiments with a smaller velocity of impact. The velocity of 20″ per sec., hitherto used, gives rise to a maximum total pressure, during impact, of about 300 lbs., which, on Hertz's theory, would produce at the centre of the circle of contact, a pressure of about 170 tons per sq. in. This pressure varies as the cube root of the velocity, so that it cannot be much reduced without a very great reduction in the withdrawal (to which the velocity is proportional). It was found, however, that if the withdrawal were much less than 2″, experimental errors began to increase, probably on account of the elasticity of the suspension. The height of fall corresponding to this withdrawal is

only $\frac{1}{30}$th of an inch and, the radius of the suspension being 60 inches, an increase in its length of only 1 in 18,000 would cause an error of 10°/₀ in the height of fall, or of 5°/₀ in the velocity. With 2″ withdrawal the end-effect is about $\frac{1}{10^4}$ secs., and this I found to vary roughly as the inverse fifth root of the velocity (the law given by Hertz for the impact of spheres), so that the above would correspond to an error of 1°/₀ in the end-effect, or to $\frac{1}{10^6}$ secs. in the duration of the impact. This error would increase as the inverse square of the velocity, or withdrawal. $\frac{1}{10^6}$ secs. corresponds roughly with one small division ($\frac{1}{2}$ mm.) on the galvanometer scale, and was consequently quite measurable. The usual range of variation, in sets of similar experiments, was only about two of these divisions, and, provided the withdrawal was not less than 2″, this was not exceeded. The times given in this paper are, for the most part, the mean values of five or six observations, and are consequently almost certainly correct to well within $\frac{1}{10^6}$ secs. The deduced values of the wave-velocities are probably correct to within $\frac{1}{2}$°/₀.

With a withdrawal of 2″ (corresponding to a max. pressure of about 108 tons to the sq. in.) the steel rods (with the exception of one pair) did not overstrain. A static test of a short specimen of the rod gave about 21 tons per sq. in. as the elastic limit of the steel in compression, so that it appears that stresses, of the extremely short duration involved in these experiments, may greatly exceed the elastic limit without producing any permanent set*. With copper and aluminium, on the other hand, overstraining could not be prevented and the readings diminished gradually with successive impacts until a steady value was reached. It appears, however, that, with careful treatment, the final state of the ends of the rods, due to the overstraining, is independent of their length, so that the straight line law still holds, and gives the correct value of the wave-velocity. In these cases two figures are given, the first being the initial reading; and the second, the mean of several readings taken after the steady state had been reached. It will be seen that two straight lines are thus obtained which are practically parallel (Fig. 7). The value of the wave-velocity is taken from the second of these, more reliance being placed on this as each reading is the mean of several observations. Moreover, the overstraining takes place more or less irregularly

* This is in agreement with Prof. Hopkinson's observations for momentary tensions.

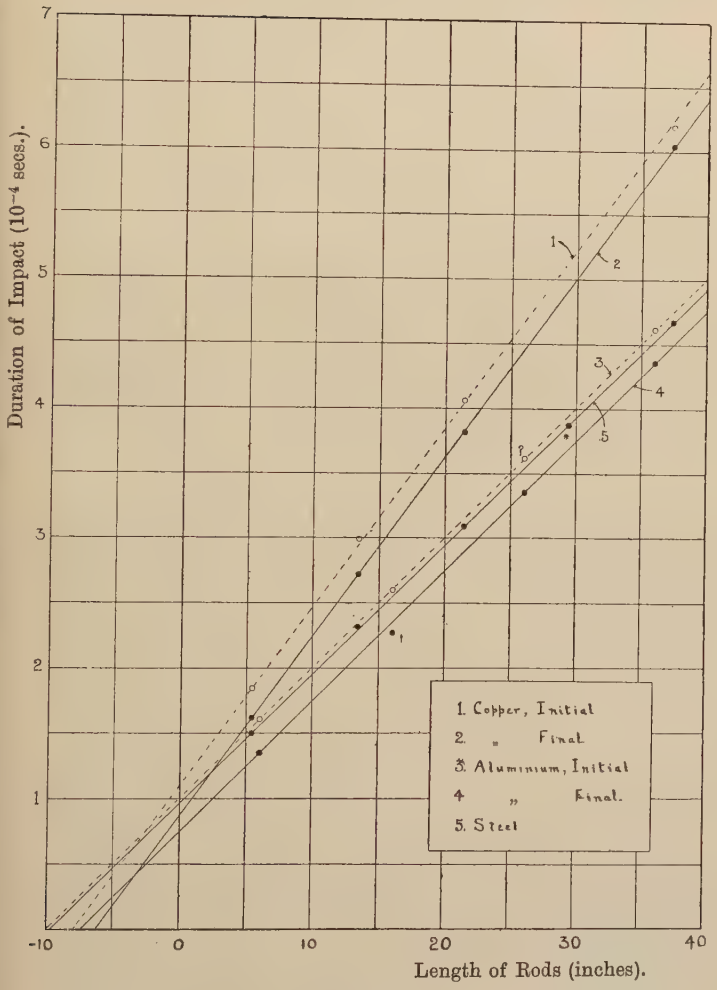

Duration of Impact (10^{-4} secs.).
7
6
5
4
3
2
1
-10
0
10
20
30
40
Length of Rods (inches).
1
2
3
4
5
1. Copper, Initial
2. " Final
3. Aluminium, Initial
4 " Final.
5. Steel

Fig. 7.

until the steady state is reached, and as it begins to take place during the first impact, the first series of readings, particularly in the case of copper, show greater deviations from the straight line law than the second. The figures are as follows:—

	Steel rods, 2″ withdrawal				
Length of rods (inches)	$5\frac{3}{8}$	$13\frac{3}{8}$	$21\frac{3}{8}$	$29\frac{3}{8}$	$37\frac{3}{8}$
Time of impact (10^{-4} secs.)	1·501	2·319	3·089	3·868*	4·675

		Copper rods, 2″ withdrawal			
Length of rods (inches)...		$5\frac{3}{8}$	$13\frac{3}{8}$	$21\frac{3}{8}$	$37\frac{3}{8}$
Time of impact (10^{-4} secs.)	Initial	1·845	2·993	4·064	6·193
	Steady	1·617	2·721	3·817	6·041

(There were no copper rods $29\frac{3}{8}$″ long, owing to lack of material when they were made.)

		Aluminium rods, 2″ withdrawal			
Length of rods (inches)...		6	16	26	36
Time of impact (10^{-4} secs.)	Initial	1·611	2·602	? 3·621	4·619
	Steady	1·349	2·272†	3·354	4·359

The values of the wave-velocities got by plotting these figures are as follows:—

Steel	16,820 ft. per sec.
Copper	12,060 ft. per sec.
Aluminium	16,620 ft. per sec.

* This pair of rods overstrained. The ends were accordingly re-turned and polished and the experiment repeated. The figure given here represents the mean of the two initial readings. In the other cases no overstraining occurred, and the figure given is the mean of five readings.

† This pair of rods overstrained to a greater extent than any of the others, the difference being easily perceptible on observing the ends as above described.

The static tests resulted as follows :—

	Steel	Copper	Aluminium
Length of Specimen (inches) .	16	18	18
Mean diameter (inches)	·5000	·4985	·5090
Weight (lbs.)	·883	1·124	·3562
Density (lbs. per cub. ft.) ...	485·7	553·0	168·1
E (lbs. per sq. in.)	29,410,000	17,220,000	9,972,000
$\sqrt{\frac{Eg}{\rho}}$ (ft. per sec.)	16,750	12,010	16,580

In determining the densities in the above table, the volume of the specimen was taken as the product of its length and mean cross-section, thus :—

$$\rho = \frac{w}{l \times \frac{\pi d^2}{4}}.$$

The values of Young's Modulus were determined in the usual way with Ewing's Extensometer. Thus if W be the total load, and x the extension per unit length, we have :—

$$E = \frac{W}{\frac{\pi d^2}{4} \times x},$$

so that the formula $v = \sqrt{\frac{Eg}{\rho}}$ reduces to the simple form $= \sqrt{\frac{W}{x} \cdot \frac{l}{w} \cdot g}$. Hence an error in the mean diameter will not affect the final result, and, the quantities l and w being determinable with great accuracy, it follows that the error in v will only be half the error in the extensometer observations.

The value of v, thus obtained, assumes that the waves are propagated isothermally, and a small correction will be necessary to get the true adiabatic value. If we denote the isothermal and adiabatic cases by the suffixes θ and ϕ respectively, a process precisely analogous to that given in Thomson and Poynting's *Text-book of Physics* (Heat, pp. 288—9), gives rise to the formula :—

$$\frac{E_\phi}{E_\theta} = \frac{1}{1 - \frac{\alpha^2 E_\theta \theta}{\rho K_p}}$$

where α is the coefficient of the *linear* expansion, θ the temperature (absolute), and K_p the mechanical equivalent of the specific heat at constant pressure. The quantity $\frac{\alpha^2 E_\theta \theta}{\rho K_p}$ is very small, and we may therefore write:—

$$\frac{E_\phi}{E_\theta} = \frac{v_\phi^2}{v_\theta^2} = 1 + \frac{\alpha^2 E_\theta \theta}{\rho K_p} \text{ or } \frac{v_\phi}{v_\theta} = 1 + \frac{1}{2}\frac{\alpha^2 E_\theta \theta}{\rho K_p}.$$

[It is interesting to compare this result with that of Duhamel*. Duhamel takes the case of uniconstant isotropy (Poisson's ratio $= \frac{1}{4}$) and gets the relation

$$\frac{E_\phi - E_\theta}{E_\phi} = \frac{1 - \frac{1}{\gamma}}{6},$$

where γ is the ratio of the specific heats at constant pressure and volume. Hence

$$\frac{E_\theta}{E_\phi} = 1 - \frac{\gamma - 1}{6\gamma} \text{ or } \frac{E_\phi}{E_\theta} = 1 + \frac{\gamma - 1}{6\gamma} = 1 + \frac{\gamma - 1}{6},$$

since γ is very nearly unity.

Now we have (Thomson and Poynting, *loc. cit.*)

$$\gamma = \frac{1}{1 - \frac{a^2 e_\theta \theta}{\rho K_p}} = 1 + \frac{a^2 e_\theta \theta}{\rho K_p},$$

where a is the coefficient of *volume* expansion, and e_θ the modulus of *volume* elasticity.

Now, $a = 3\alpha$ and, taking Poisson's ratio $= \frac{1}{4}$, $e_\theta = \frac{2}{3} E_\theta$, so that, for this case,

$$\frac{E_\phi}{E_\theta} = 1 + \frac{\alpha^2 E_\theta \theta}{\rho K_p} = 1 + \frac{1}{6}\frac{a^2 e_\theta \theta}{\rho K_p} = 1 + \frac{\gamma - 1}{6},$$

which agrees with Duhamel's result.]

The following figures, with the exception of the first row, are taken from Wrapson and Gee's Mathematical and Physical Tables.

	Steel	Copper	Aluminium
E_θ (lbs. per sq. in.)...	$29{\cdot}5 \times 10^6$	17×10^6	10×10^6
α	·000011	·000017	·000024
ρ (c.g.s.).....	7·8	8·8	2·6
K_p (c.g.s.)	$\cdot 113 \times J$	$\cdot 093 \times J$	$\cdot 21 \times J$

$J = 4{\cdot}2 \times 10^7$.

* Todhunter and Pearson, *Hist. of Elasticity*, Vol. I. § 889.

Using these figures, the ratio $\frac{v_\phi}{v_\theta}$ has the following values:—

Steel	1·001
Copper	1·0015
Aluminium	1·0026

so that we get the following table of velocities:—

Velocity	Observed	Calculated	
		Isothermal	Adiabatic
Steel	16,820	16,750	16,770
Copper	12,060	12,010	12,030
Aluminium.....	16,620	16,580	16,620

The agreement between the first and last columns is very close indeed, the difference in the worst case, that of steel, being only °/₀. This is well within the limits of experimental error, and we may therefore assume that Young's Modulus has the same value whether the loading is slow or sudden.

We now turn to a more detailed consideration of the experimental work. The rods were adjusted by means of the brass regulators (*A*, Fig. 2 A). The upper ends of the suspending cords passed through small holes in the faces of these regulators, and then through similar holes in the blocks (*B*, Fig. 3) to the pegs, *A*,

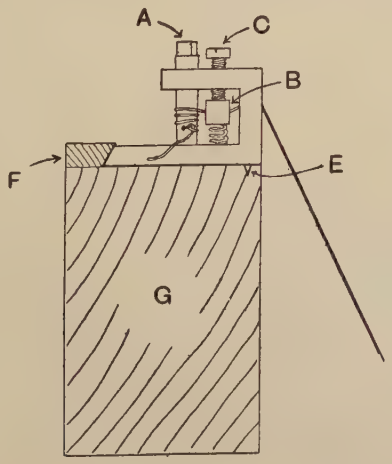


Fig. 3.

by means of which coarse adjustments were effected. Fine adjustments were made by raising or lowering the blocks, *B*, by means of the screws, *C*. The regulators could easily be fixed at any point along the wooden beams by first wedging the bevelled edge, *D*, under the guide, *F*, and then pressing home the sharp pins, *E*. At their lower ends the suspending cords were attached to the rods by small loops, which passed over little hooks screwed into the rods (*A*, Fig. 4). In order to get the axes of the rods

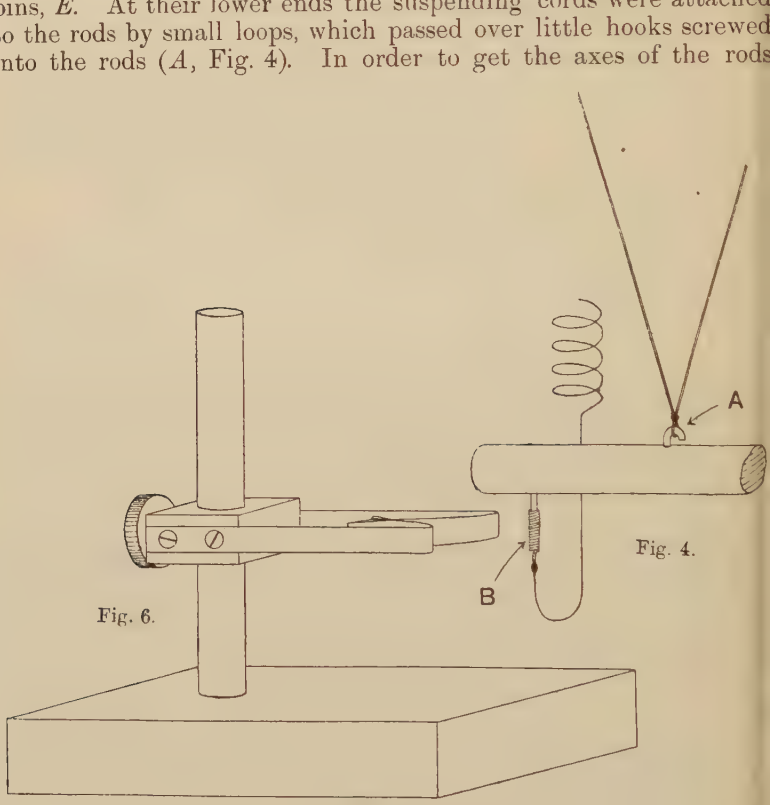


Fig. 4.

Fig. 6.

collinear, four long threads of cotton (*C*, Fig. 2 A) were stretched between two brass plates, *E*, in a vertical plane midway between the two beams, and the rods so adjusted as to lie just in between them without touching any of them. As a matter of fact it was found that, when the rods had been nearly adjusted in this way the best test of axial collinearity was the complete absence of the note due to the transversal vibrations of the rods, when they were allowed to impinge. The note due to the longitudinal vibrations being much higher than this, was easily distinguishable from it and, moreover, so little energy was taken up in longitudinal vibrations (the two rods being equal), that very little "ring" was associated with this form.

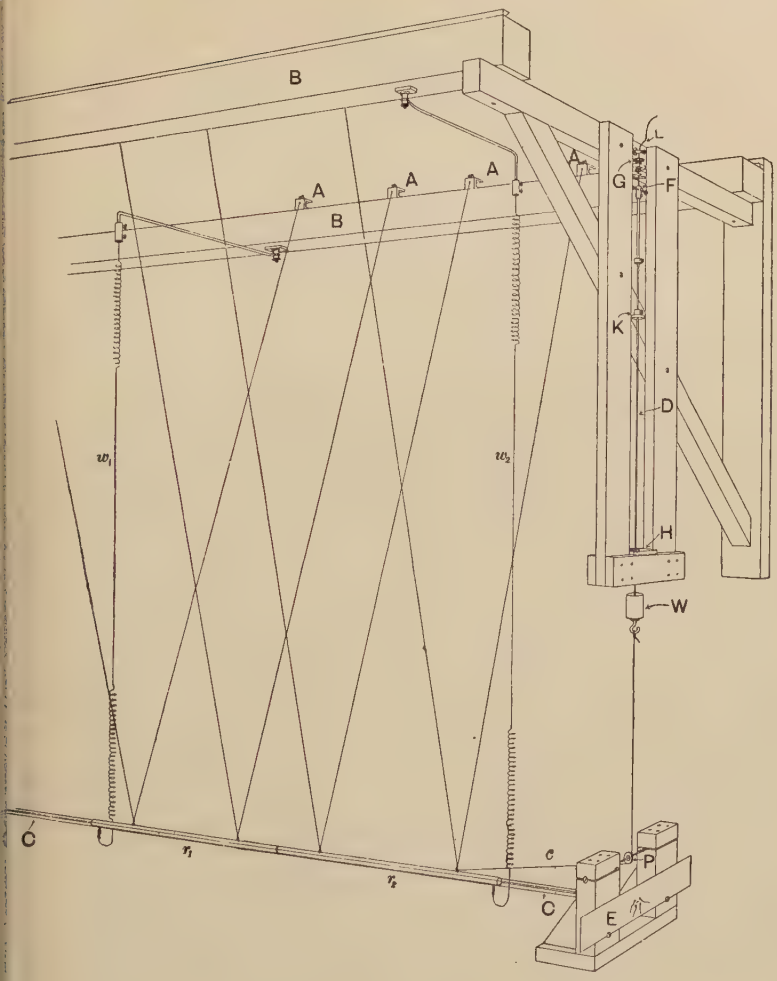


Fig. 2 A.

Collinearity being thus attained, the rod r_2 (Fig. 2 A), was withdrawn by means of the cord, *c*, to a distance measured, as described, by a travelling telescope. This cord is attached to the rod by one of the hooks, and passes under a small pulley, *P*, to a hook at the bottom of the dropper, *D*. The latter is supported by the fuse-wire, *L*, which passes through a hole in the stop, *G*, and is fixed by a binding screw above (Fig. 5). The fuse wire is pulled up as high as it will go, so that the top of the dropper is pulled up against the stop, *G*; the arms, *Q*, at the same time making contact

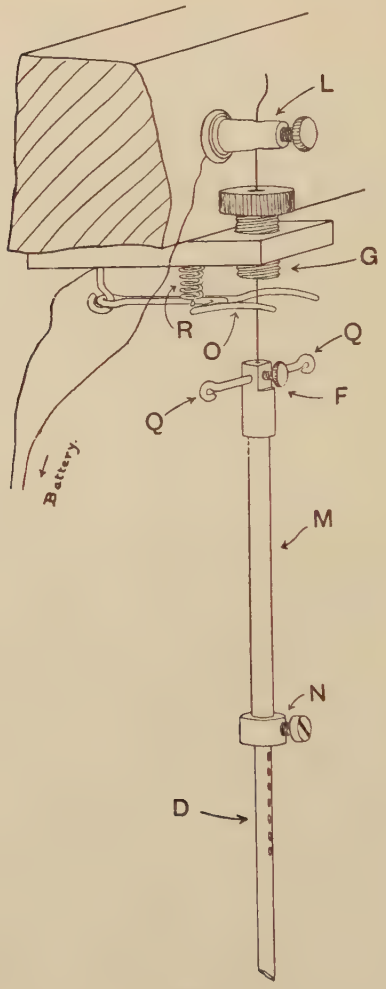


Fig. 5.

with the fork, *O*. The withdrawal can be roughly adjusted by sliding the wire, *D*, up and down the tube, *M*, and clamping by means of the screw, *N*. Fine adjustment is obtained by screwing the stop, *G*, up or down. The release is then effected by blowing the fuse, and when once the adjustment has been properly made the same withdrawal may be repeated as often as we please by simply inserting fresh fuse wires. When the fuse is blown, it will be seen that the dropper falls freely with the acceleration of gravity. The rod, however, starts with a much smaller accelera

tion, so that the release is extremely clean. Two points are of importance in using such an arrangement. First, the cord must be as inelastic as possible, for the time which elapses before the tension in the cord falls from its initial value to zero, is the time required by the dropper to gain on the rod a distance equal to the stretch of the cord under the original tension. Originally some of the fishing line used for suspending the rods was also used for this purpose. This line is very inelastic, but it was found when dealing with lighter rods (particularly aluminium) that this was more than counterbalanced by its rigidity, and it was replaced in the later experiments by strong cotton, which answered very well. Secondly, during the very short time that this change of tension inevitably occupies, the cord remains in contact with the pulley, and imparts a certain amount of spin to it. In order to make the energy thus lost as small as possible, it is necessary to keep down the friction and moment of inertia of the pulley. The pulley used was for this reason made of boxwood mounted on a light steel shaft which ran between two fine pivots at its ends. The release then proved most reliable and easy to manipulate. The dropper passes through a hole in the rubber block (*H*, Fig. 2 A) on which it is caught by means of the collar, *K*, and so prevented from falling on to the pulley.

The electric leads to the rods were made of fine silk-covered copper wire, formed into a helix top and bottom so as to be perfectly flexible (w_1, w_2, Fig. 2 A). They were attached to the rods by pushing a small helical spring (*B*, Fig. 3) over a pin in the end of the rod. This formed a very light and good connection. A spring catch (Fig. 6) was provided, which, after the first impact, caught the pin in the rod, r_1, and so prevented a second impact from occurring while the galvanometer was being read. The sketch explains itself.

We now come to the actual testing of the apparatus. The complete connections of the system are shown in Fig. 1 A, where

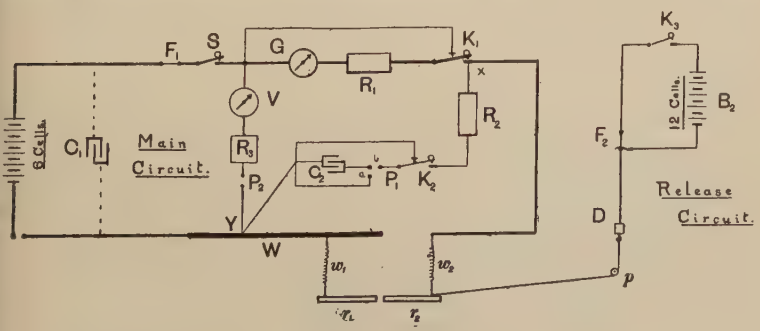


Fig. 1 A.

C_2 represents the standard condenser used in calibrating the galvanometer. In using this instrument, it was necessary to throw it in or out of the circuit instantaneously, owing to the leakage effects, which persisted in spite of the most careful insulation. For this reason the short-circuiting key, K_2, was inserted. On depressing this key, the galvanometer receives its true impulse, the whole charge on the condenser passing through it before any leakage currents have time to produce an appreciable effect. The result of the calibration was to give an exact straight line over the range in which the galvanometer was used. This line, however, does not pass quite through the zero, and this effect was finally traced to the condenser; a similar calibration, in which the condenser was *discharged*, instead of charged, giving a straight line, parallel to the first, but passing on the other side of the origin. The error appears quite insignificant on plotting, but it is sufficient to account for the fact that the flings recorded later on, as the result of charging the smaller capacities to higher potentials, apparently do not quite agree with the value we should expect from the galvanometer constant taken from the straight line. This constant is found to be: $q = 2{\cdot}945 \times 10^{-8}\,\delta$ where q is in coulombs, and δ in scale divisions.

[With regard to the rest of the connections, C_1 is a condenser inserted in order to ensure the E.M.F. keeping constant during the sudden discharge, as any variation occupying so short a time would have no effect on the voltmeter. It is not essential. The resistance, R_1, was so inserted as to be always in circuit with the galvanometer, even when the latter was shorted, as it was found that the violent damping effect caused by direct shorting continually altered the zero of the galvanometer. W is a thick copper wire, of negligible resistance, to any point of which the lead, w_1, could be clamped, and F_1 is a fuse wire to provide against accidental short-circuits.]

We have lastly to consider the working of the circuit with a view to determining the necessary corrections. In the normal experiment, the rods were adjusted, the galvanometer key depressed, and, when the spot had come to rest at zero, the fuse was blown and a reading taken. The contact-resistance between the rods being negligible compared with the whole resistance of the circuit, it follows that when the rods first impinge, the resistance falls to its final value, R_1 (= 5000) practically instantaneously. We may therefore treat the circuit as having this constant resistance during the growth of the current at the beginning of the impact. The equation for this growth then becomes:—

$$L\frac{di}{dt} + R_1 i + V = 0 \quad \text{or} \quad i = \frac{V}{R_1}\left(1 - e^{\frac{R_1}{L}t}\right),$$

where i is the current, V the voltage, and L the self-induction of the circuit. In order that the current should attain a value sensibly equal to $\frac{V}{R_1}$, before the end of the contact, it is necessary that $\frac{R_1}{L}$ shall be as large as possible. The self-induction, L, is almost entirely due to the coil of the galvanometer, and, owing to the peculiar construction of the latter, was very small indeed, so that, with the large value of R_1 employed, the above condition was easily fulfilled.

Integrating the above equation, we get:—

$$q = \frac{V}{R_1}\left\{T - \frac{L}{R_1}\left(1 - e^{-\frac{R_1}{L}t}\right)\right\}.$$

Now $\frac{L}{R_1}$ and $e^{-\frac{R_1}{L}t}$ are both very small quantities, and we may certainly neglect their product, so that we get:—

$$q = \frac{V}{R_1}\left(T - \frac{L}{R_1}\right) \quad \text{or} \quad T = \frac{R_1}{V}q + \frac{L}{R_1} \ldots\ldots\ldots\ldots (2).$$

This gives the correction for self-inductive growth of the current, which is a constant addition to the time. There may also be a correction for spark at break, and this remains to be investigated.

The simplest method of getting an absolute value of the time would be to charge a condenser to a known voltage, partially discharge it through the rods during impact, and then compare the flings produced on the galvanometer by the whole charge, and by the remainder after impact. By this means we should have no self-induction or spark effects accompanying the discharge through the rods, and the self-induction of the galvanometer would not matter. It was, however, quite impossible to do this, owing to leakage between the various operations, and a modified method had to be adopted. For this purpose the standard condenser (C_2, Fig. 1 A) was used, in the same configuration as in calibrating the galvanometer. The resistance round the main circuit from X to Y being very small, it follows that if the resistances, R_1, R_2, are both kept large, the potential difference between X and Y, when the rods are in contact and currents flowing, will be very small compared with the whole potential employed. The currents flowing in the circuit $C_2K_2Xr_2r_1YC_2$, and in the main circuit, $B_1GXr_2r_1YB_1$, will therefore be entirely independent of each other. Thus if we charge the condenser, C_2, and then hold down both the keys, K_1 and K_2 while the impact takes place, we shall get the same current running

through the galvanometer up to the instant when the rods separate, as though the condenser circuit were not there. At the same time the condenser will be discharging itself through the resistance, R_2, at the same rate as if the galvanometer circuit did not exist. At the instant when the rods separate, however, the conditions change. The current which is flowing through the galvanometer is not now suddenly reduced (as in the normal experiment) but is simply diverted to the path XR_2C_2Y, and flows into the condenser, so that no spark is produced. Current continues to flow through the galvanometer into the condenser until the latter is once more charged to its original potential. All these events follow one another within a very small fraction of a second, so that there is no time for leakage currents to produce any effect. The galvanometer will, therefore, register a fling which is the same as that obtained in the normal experiment (less the part, if any, due to spark) plus that due to the quantity discharged by the condenser round the circuit $C_2K_2Xr_2r_1YC_2$.

Consider this latter part.

If x be the charge on the condenser at any instant, we have :—

$$\frac{x}{C_2} = -R_2\dot{x} \quad \text{or} \quad \dot{x} + \frac{x}{R_2C_2} = 0,$$

whence $$x = VC_2 e^{-\frac{t}{R_2C_2}},$$

VC_2 being the initial charge.

If, then, the duration of the impact be T, the whole quantity discharged will be

$$VC_2\left(1 - e^{-\frac{T}{C_2R_2}}\right) \ldots \ (= y, \text{ say}).$$

Hence $$e^{-\frac{T}{C_2R_2}} = 1 - \frac{y}{VC_2}$$

or $$T = -C_2R_2 \log_e\left(1 - \frac{y}{VC_2}\right) = C_2R_2 \log_e\left(\frac{VC_2}{VC_2 - y}\right) \ldots (3).$$

To determine the value of the spark effect by this method, it is only necessary to make C_2R_2 so small that, in the above, $e^{-\frac{T}{C_2R_2}}$ is negligible compared with unity. We then have $y_1 = VC_2$ simply, so that, if we take two galvanometer readings, one, Q, with the normal form of experiment, and one, Q', with the condenser, we shall have :—

$$Q' = Q - \text{Spark} + y_1 \quad \text{or} \quad \text{Spark} = Q + VC_2 - Q' \ldots\ldots (4).$$

To determine T we need a further reading, Q'', with a greater value of C_2R_2. We then get $Q'' = Q - \text{Spark} + y_2$, so that

$$Q' - Q'' = y_1 - y_2 \quad \text{or} \quad y_2 = VC_2 + Q'' - Q' \ldots\ldots\ldots (5).$$

We then have, from (3),

$$T = C_2R_2 \log_e \left(\frac{VC_2}{VC_2 - y_2}\right)$$

$$= C_2R_2 \log_e \left(\frac{VC_2}{Q' - Q''}\right)$$

which gives the absolute value of the time free from all corrections.

It would not be convenient to repeat this process for every experiment; but it was carried through with the shortest steel rods, and, by comparing the result with that got by the normal method, the necessary corrections for the latter were obtained.

To determine the best value of C_2R_2 to use in this method, we may proceed as follows:—

$$T = -C_2R_2 \log_e (1 - y/VC_2),$$

$$\therefore \quad \frac{dT}{dy} = -C_2R_2 \times \frac{1}{(1 - y/VC_2)} \times -\frac{1}{VC_2},$$

or

$$dT = \frac{R_2}{V} e^{-\frac{T}{C_2R_2}} dy,$$

so that, for a given error in y, the error in T is least when $R_2 e^{\frac{T}{C_2R_2}}$ is a minimum.

Differentiating, with regard to R_2, we get the condition

$$e^{\frac{T}{C_2R_2}} + R_2 \times -\frac{T}{C_2R_2^2} e^{\frac{T}{C_2R_2}} = 0 \quad \text{or} \quad \frac{T}{C_2R_2} = 1.$$

For the case considered, T was about $1{\cdot}5 \times 10^{-4}$ secs. R_2 was therefore taken as 3000 ohms, and C_2 as $\cdot 05 \times 10^{-6}$ farads. In determining the spark effect, R_2 was reduced to 300 ohms, so that $e^{-\frac{T}{C_2R_2}} = e^{-10}$ about, and is, consequently, quite negligible compared with unity. The figures obtained were as follows:—

Impact tests	(*a*) Normal experiment	1·002 ...	Q
	(*b*) With condenser, $R_2 = 3000$ ohms	2·062 ...	Q''
	(*c*) With condenser, $R_2 = 300$ ohms...	2·674 ...	Q'
	(*d*) Charging condenser direct... ...	1·676 ...	VC_2

Each of the above figures represents the ratio of the galvanometer fling to the voltage, and is the mean of several observations, which are given in full in the tables. In the first place it is seen that $(a) + (d) = 2{\cdot}678$, while $(c) = 2{\cdot}674$. From this we conclude that there is no sparking effect whatever, such a small difference being

easily accounted for by the back E.M.F. produced by the condenser discharge passing between X and Y, when R_2 is as small as 300 ohms. Assuming this, we have $\frac{(b)-(a)}{(d)} = \frac{y_2}{VC_2}$, so that

$$T = -C_2R_2 \log_e\left(1 - \frac{y_2}{VC_2}\right)$$

$$= -\cdot 05 \times 10^{-6} \times 3 \times 10^3 \log_e\left(1 - \frac{1\cdot 060}{1\cdot 676}\right)$$

$$= 1\cdot 5 \times 10^{-4} \log_e 2\cdot 720$$

$$= 1\cdot 501 \times 10^{-4} \text{ secs.}$$

Now, since there is no sparking effect, the equation (2) is true.

$$\therefore \quad T = R_1 \times \frac{Q}{V} + \frac{L}{R_1}$$

and $$\frac{Q}{V} = 2\cdot 945 \times 10^{-8} \times \frac{\delta}{V} = 2\cdot 945 \times 10^{-8} \times (a);$$

$$\therefore \quad T = 5000 \times 2\cdot 945 \times 10^{-8} \times 1\cdot 002 + \frac{L}{R_1}$$

or $$1\cdot 501 \times 10^{-4} = 1\cdot 476 \times 10^{-4} + \frac{L}{R_1},$$

whence $$\frac{L}{R_1} = \cdot 025 \times 10^{-4} \text{ secs.},$$

which is the correction required.

The work was carried out at the Engineering Laboratory, Cambridge, under the guidance of Prof. Hopkinson, whose practical interest contributed largely to its ultimate success.

The tables of observations, from which the figures in this paper are deduced, here follow. It will be noted that below each table is a figure called the "Fuse key fling." This was a small fling which was always produced in the galvanometer on depressing the fuse key, even when no impact of the rods took place. In the earlier experiments it was somewhat larger than the values here recorded, and it was found necessary to deduct it from the nett fling before consistent results could be obtained. The various columns in the tables are as follows:—

V ... ... Voltage,
Z ... ... Zero of Galvanometer,
F ... ... Fling of Galvanometer,
δ ... ... Corrected fling ($= F - Z -$ Fuse key fling),
M ... ... Mean,
T ... ... Time $\left(= \frac{5000 \times 2\cdot 945}{10^4} \frac{\delta}{V} + \cdot 025\right)$ (10^{-4} secs.).

Test of $5\frac{3}{8}$″ Steel Rods, 2″ withdrawal.

(*a*) Normal, $R_1 = 5000$ ohms.

V	*Z*	*F*	δ	δ/V	*M*	*T*
12·16	5·25	17·65	12·25 –	1·005		
12·13	5·3	17·7	12·25 –	1·007		
12·12	5·3	17·65	12·20 –	1·004	1·002	1·501
12·12	5·3	17·55	12·10 –	·995		
12·12	5·3 +	17·6 +	12·15 –	1·000		

Fuse key fling, ·15 +

(*b*) With Condenser, $R_2 = 3000$ ohms.

12·15	5·3 –	30·45	25·0	2·057		
12·13	5·3	30·5 –	25·0	2·061		
12·12	5·3 +	30·6 –	25·1 –	2·068	2·062	—
12·12	5·3 +	30·5	25·0	2·063		
12·12	5·4 –	30·5 +	25·1 –	2·060		

Fuse key fling, ·15 +

(*c*) With Condenser, $R_2 = 300$ ohms.

12·14	5·3	37·9	32·45 –	2·670		
12·13	5·3 +	37·9	32·4	2·671		
12·12	5·3 +	38·0 –	32·5 –	2·680	2·674	—
12·12	5·35	37·95	32·45 –	2·674		
12·12	5·4 –	38·0 –	32·45 –	2·674		

Fuse key fling, ·15 +

(*d*) Charging Condenser direct.

12·13	5·3	25·6 +	20·3 +	1·676	1·676	—
12·13	5·3	25·6 +	20·3 +	1·676		

There is here, of course, no Fuse key fling.

Test of $13\frac{3}{8}''$ *Steel Rods,* 2″ *withdrawal.*

V	Z	F	δ	δ/V	M	T
12·13	2·3 +	21·3 –	18·80	1·550		
12·14	2·3 +	21·5 –	19·00	1·566		
12·13	2·35	21·35	18·85	1·554	1·557	2·319
12·12	2·35	21·4	18·90	1·560		
12·12	2·35	21·3	18·80	1·555		

Fuse key fling, ·15.

Test of $21\frac{3}{8}''$ *Steel Rods,* 2″ *withdrawal.*

12·13	5·1 –	30·5	25·3	2·085		
12·13	5·05	30·4 +	25·25	2·082		
12·125	5·05	30·4 –	25·2	2·079	2·080	3·089
12·12	5·05	30·4 –	25·2	2·079		
12·12	5·05	30·3	25·15 –	2·073		

Fuse key fling, ·10 +

Test of $29\frac{3}{8}''$ *Steel Rods,* 2″ *withdrawal* (Initial Readings).

12·12	3·0	34·9	31·75	2·620	2·609	3·868
12·36	2·1 +	34·4	32·15 –	2·599		

Fuse key fling, ·15.

Test of $37\frac{3}{8}''$ *Steel Rods,* 2″ *withdrawal.*

12·15	5·7 +	44·25	38·35	3·157		
12·13	5·7 +	44·2	38·3	3·158		
12·13	5·7 +	44·15	38·25	3·154	3·157	4·675
12·13	5·7 +	44·2 +	38·3 +	3·160		
12·12	5·7 +	44·15	38·25	3·156		

Fuse key fling, ·15 +

Test of $5\frac{3}{8}''$ *Copper Rods,* 2″ *withdrawal.*

First six readings taken, showing influence of overstrain.

V	*Z*	*F*	*δ*	*δ/V*	*M*	*T*
12·18	2·1	17·3	15·05	1·236	1·236	1·845
12·18	2·1	16·2	13·95			
12·17	2·1	15·8	13·55			
12·17	2·1	15·55	13·3			
12·17	2·15	15·45	13·15	1·081	1·081	1·617
12·16	2·15	15·45	13·15	1·081		

Fuse key fling, ·15.

The gradual diminution of the time of impact, due to the overstraining of the ends of the rods, is well shown in the above table. Unfortunately, in subsequent observations with this pair of rods, great irregularities occurred in the readings, of the kind usually associated with dirt on the ends of the rods, and I was not able to get a steady value by repolishing, as was the case in other experiments. The mean of the last two readings was therefore taken as the time to be plotted, since it is fairly clear that overstraining was practically complete when they were taken.

Test of $13\frac{3}{8}''$ *Copper Rods,* 2″ *withdrawal.*

	V	*Z*	*F*	*δ*	*δ/V*	*M*	*T*
Initial	12·14	2·7	27·3	24·45	2·015		2·993
	12·12	2·0	24·3	22·1 +	1·826		
	12·12	2·1 –	24·4 –	22·1 +	1·826		
Steady	12·12	2·1 –	24·5	22·25	1·836	1·830	2·721
	12·11	2·1 –	24·35	22·1	1·827		
	12·11	2·1 –	24·45	22·2	1·833		

Fuse key fling, ·15 for initial reading, ·2 – for steady.

Test of $21\frac{3}{8}''$ *Copper Rods,* 2″ *withdrawal.*

	V	*Z*	*F*	*δ*	*δ*/*V*	*M*	*T*
Initial	12·11	2·5 +	35·8	33·15	2·736	2·742	4·064
	12·11	2·55	35·95	33·3 –	2·748		
Steady	12·10	2·6 –	33·8 +	31·15 –	2·572	2·574	3·817
	12·10	2·6 –	33·75	31·05	2·566		
	12·10	2·6	33·85	31·15 –	2·572		
	12·10	2·6	34·0 –	31·25	2·583		
	12·10	2·6	33·8	31·1 –	2·568		
	12·10	2·6	34·0 –	31·25	2·583		

Fuse key fling, ·10 +

Test of $37\frac{3}{8}''$ *Copper Rods,* 2″ *withdrawal.*

Initial	12·16	2·15	53·35	51·15 –	4·205		6·193
Steady	12·11	2·30	52·0	49·55 –	4·091	4·085	6·041
	12·11	2·30	52·0	49·55 –	4·091		
	12·11	2·30 +	51·8	49·3	4·070		
	12·11	2·30 +	51·95	49·45	4·083		
	12·11	2·30 +	51·8 +	49·35 –	4·074		
	12·11	2·30 +	52·1 +	49·65 –	4·101		

Fuse key fling, ·15 + (Initial ·05 +)

Test of 6″ *Aluminium Rods,* 2″ *withdrawal.*

Initial	12·10	2·35	15·70	13·25 –	1·044		1·611
Steady	12·10	6·0 +	17·2 –	11·05 –	·9114	·8995	1·349
	12·10	6·0 +	16·85	10·70	·8843		
	12·10	6·05	17·15	11·0 –	·9076		
	12·10	6·05	16·95	10·8 –	·8910		
	12·10	6·05	17·10	10·95 –	·9033		

Fuse key fling, ·10 +

Test of 16″ *Aluminium Rods,* 2″ *withdrawal.*

	V	*Z*	*F*	*δ*	*δ*/*V*	*M*	*T*
Initial	12·12	6·2	27·55	21·25 –	1·751		2·602
	12·11	6·2 +	24·8 –	18·45 –	1·522		
	12·11	6·2 +	24·9 –	18·55 –	1·531		
Steady	12·11	6·2 +	24·9	18·55	1·532	1·526	2·272 †
	12·11	6·25	24·8 +	18·45	1·524		
	12·11	6·25	24·8 +	18·45	1·524		

Fuse key fling, ·10 +

Test of 26″ *Aluminium Rods,* 2″ *withdrawal.*

Initial	12·11	5·7	38·35 ? 35·35	32·6 – ? 29·6 –	2·691 ? 2·443		3·987 ? 3·621
	12·10	5·75	33·2	27·4 –	2·263		
	12·10	5·8 –	33·3 –	27·45 –	2·268		
Steady	12·10	5·8	33·05	27·2 –	2·247	2·262	3·354
	12·10	5·8	33·15	27·3 –	2·255		
	12·10	5·8	33·4	27·55 –	2·275		

Fuse key fling, ·05 +

The figures marked (?) in the above table are got by substituting 35·35 for 38·35 in column *F*. I have noticed a tendency to mistake the figures 5 and 8, when working rapidly, and it will be seen that the change in this case brings a reading, which otherwise would be hopelessly out of agreement with all the other results, well into line with them. The second reading was 34·35.

Test of 36″ *Aluminium Rods,* 2″ *withdrawal.*

Initial	12·12	6·35	44·3	37·85 –	3·121		4·619
	12·11	6·35	42·2	35·75 –	2·951		
	12·11	6·35	42·2	35·75 –	2·951		
Steady	12·11	6·4 –	42·2 +	35·75 –	2·951	2·944	4·359
	12·11	6·4 –	42·25	35·75	2·952		
	12·11	6·4 –	41·8	35·3	2·916		
	12·11	6·4 –	42·2 –	35·7 –	2·946		

Fuse key fling, ·10 +

Static tests of Steel Specimen.

Length ... ... 16″.
Mean diam. ... ·500″.
Weight ... ... ·883 lbs.
Density ... ... 485·7 lbs. per cub. ft.

Extensometer test.

Calibration of Instrument... 1 div. = 1/960″.
Length under test ... ... 8″.

Load (lbs.)	Reading	Difference	Return	Difference
0	4·60	0	?	?
500	5·19	·59	5·25	·65
1000	5·86	1·26	5·90	1·30
1500	6·52	1·92	6·60	2·00
2000	7·19	2·59	7·28	2·68
2500	7·85	3·25	7·92	3·32
3000	8·52?	3·92	8·59	3·99
3500	9·20	4·60	9·24	4·64
4000	9·85	5·25	9·85	5·25

Plotting, we see that 4700 lbs. give 6·25 divs. extension.

$$\therefore\ E = \frac{8 \times 960 \times 4700 \times 16}{\pi \times 6{\cdot}25} = 29{,}410{,}000 \text{ lbs. per sq. in.}$$

Hence
$$v = \sqrt{\frac{Eg}{\rho}} = \sqrt{\frac{29{\cdot}41 \times 10^6 \times 32{\cdot}18 \times 144}{485{\cdot}7}}$$
$$= 16{,}750 \text{ feet per sec.}$$

Static tests of Copper Specimen.

Length ... ... 18″.
Mean diam. ... ·4985″.
Weight ... ... 1124 lbs.
Density ... ... 553 lbs. per cub. ft.

Extensometer test.

Calibration of Instrument... 1 div. = 1/960″.
Length under test ... ... 8″.

Load (lbs.)	Reading	Difference	Return	Difference
0	7·19	0	7·13	– ·06
250	7·70	·51	7·67	·48
500	8·22	1·03	8·26	1·07
750	8·80	1·61	8·85	1·66
1000	9·37	2·18	9·42	2·23
1250	9·95	2·76	10·00 (5·20)	2·81
1500	10·51 (5·71)	3·32	5·76	3·37
1750	6·30	3·91	6·30	3·91
2000	6·85	4·46	6·85	4·46

Plotting, we see that 1750 lbs. give 4 divs. extension.

$$\therefore \quad E = \frac{8 \times 960 \times 1750 \times 4}{\times \pi \times (\cdot 4985)^2} = 17{,}220{,}000 \text{ lbs. per sq. in.}$$

Hence $$v = \sqrt{\frac{Eg}{\rho}} = \sqrt{\frac{17{,}220{,}000 \times 32{\cdot}18 \times 144}{553}}$$

$$= 12{,}010 \text{ ft. per sec.}$$

Static tests of Aluminium Specimen.

Length ... ... 18″.
Mean diam. ... ·509″.
Weight ... ... ·3562 lbs.
Density ... ... 168·1 lbs. per cub. ft.

Extensometer test.

Calibration of Instrument... 1 div. = 1/966″.
Length under test ... ... 8″.

Load (lbs.)	Reading	Difference	Load (lbs.)	Reading	Difference	Mean
0	3·98	0	0	4·00	0	0
200	4·70	·72	200	4·77	·77	·745
400	5·49	1·51	400	5·50	1·50	1·505
600	6·26	2·28	600	6·29	2·29	2·285
800	7·02	3·04	800	7·05	3·05	3·045
1000	7·80	3·82	1000	7·83	3·83	3·825
1200	8·59	4·61	1200	8·60	4·60	4·605
1000	7·83	3·85	1000	7·89	3·89	3·87
800	7·08	3·10	800	7·10	3·10	3·10
600	6·30	2·32	600	6·35	2·35	2·335
400	5·54	1·56	400	5·59	1·59	1·575
200	4·79	·81	200	4·80	·80	·805
0	4·00	·02	0	4·04	·04	·03

Plotting, we see this gives 4·64 divs. for 1200 lbs. when loading and 4·60 when unloading. Taking the mean of these 4·62, we get :—

$$E = \frac{8 \times 966 \times 1200 \times 4}{4{\cdot}62 \times \pi \times (\cdot 509)^2} = 9{,}868{,}000 \text{ lbs. per sq. in.}$$

Hence
$$v = \sqrt{\frac{Eg}{\rho}} = \sqrt{\frac{9{,}868{,}000 \times 32{\cdot}18 \times 144}{168{\cdot}1}}$$
$$= 16{,}490 \text{ ft. per sec.}$$

It was found that the difference between the values on loading and unloading was attributable to gradual creeping, and the experiment was therefore tried of running the full load on suddenly, and then after running past it and back to it again, so as to exclude the friction effect of the machine, suddenly unloading. The values on loading and unloading then became equal, and both slightly less than before. The readings are as follows :—

Load (lbs.)	Reading	Difference	Mean
0	4·14	4·57	4·570
1200	8·71		
1200	8·71	4·54	
0	4·17		
0	4·19	4·58	
1200	8·77		
1200	8·79	4·59	
0	4·20		

Using this value we get

$$E = \frac{8 \times 966 \times 1200 \times 4}{4{\cdot}57 \times \pi \times (\cdot 509)^2} = 9{,}972{,}000 \text{ lbs. per sq. in.},$$

whence

$$v = \sqrt{\frac{9{,}972{,}000 \times 32{\cdot}18 \times 144}{168{\cdot}1}} = 16{,}580 \text{ ft. per sec.}$$

It is this value of v which is used in comparison with the dynamic method.

It is just possible that, by similar treatment, the copper specimen might also have yielded a slightly higher value.

Calibration of Galvanometer. Volts kept steady at 2·400.

C. 10^{-6} Farads.	Galvanometer				C. 10^{-6} Farads.	Galvanometer			
	Zero	Fling	Net fling	Mean		Zero	Fling	Net fling	Mean
·05	4·6 –	8·6 –	4·0	4·01	·4	4·65	37·15	32·5	32·53
	4·6	8·6 +	4·0 +			4·65	37·20	32·55	
	4·6	8·6	4·0			4·6 +	37·2 –	32·55	
	4·6	8·6 +	4·0 +			4·65	37·2 –	32·55 –	
·1	4·6	12·7	8·1	8·09	·5	4·65	45·3 +	40·65 +	40·67
	4·6	12·7	8·1			4·65	45·3 +	40·65 +	
	4·6	12·7 –	8·1 –			4·65	45·3	40·65	
	4·6	12·7	8·1			4·65	45·3 +	40·65 +	
·2	4·6 +	20·9 –	16·25	16·24	·6				48·85
	4·6 +	20·85	16·25 –			4·45	53·3	48·85	
	4·6 +	20·9 –	16·25			4·45	53·3	48·85	
	4·6 +	20·85	16·25 –						
·3	4·6 +	29·0	24·4 –	24·35	·8				65·17
	4·6 +	29·0 –	24·35			4·45	69·6 +	65·15 +	
	4·6 +	28·95	24·3 +			4·4 +	69·6	65·2 –	
	4·6 +	29·0 –	24·35						

Plotting gives an absolutely straight line, with the relation

$$q = 2{\cdot}945 \times 10^{-8}\,\delta.$$

The number of Electrons in an Atom. By NORMAN CAMPBELL, M.A., Trinity College.

[*Read* 6 *May*, 1907.]

1. When the experiments of Kaufmann proved that the whole, or the greater part, of the mass of an electron is of electromagnetic origin, it seems to have been generally assumed that the mass of an atom is the sum of the masses of the electrons contained in it, and consequently that the number of electrons in the atom (N) is given by the relation

$$N = A\,\frac{M}{\mu},$$

where A is the atomic weight, M the mass of a hydrogen atom and μ the mass of an electron. But at the same time it has been recognised that, apart from arguments based on the nature of mass, there is no evidence that the number of electrons in the atom is nearly so great as would be indicated by that formula.

Lately, Prof. Thomson* has aroused fresh interest in the subject by adducing arguments to prove that the number of electrons in an atom is equal to—or at any rate of the same order of magnitude as—the atomic weight. His arguments do not appear to me entirely conclusive, and it seems desirable that any evidence, however slight, that bears on this important problem should be brought to light. The arguments that I have to offer are extremely speculative, and the only excuse that I have for putting them forward is the absence of more definite information.

2. Prof. Thomson's arguments are three in number. The first is based upon the dispersion of light and is similar to that advanced by Drude†. The latter author concluded that the numbers of electrons in an atom, which influence the dispersion of visible light, is of the same order of magnitude as the valency of the atom—a result with which Prof. Thomson's figures are in agreement: he also indicated that there must be a larger number of electrons, which have free periods so short that they cannot influence the dispersion of visible light.

The second argument is based on the emission of secondary Röntgen rays. Since it is well known that the number of atoms ionised by the most powerful Röntgen rays is only a very small

* *Phil. Mag.* 6, xi. p. 769, 1906. † *An. Phys.* 14, p. 677, 1904.

fraction of the number of atoms in the gas through which the rays pass, perhaps it may be doubted whether the number of electrons which come within the action of the rays is a fair measure of the whole number of electrons in the gas. Moreover, if there are present, as Drude indicates, electrons with very short natural periods, these electrons would play no part in the emission of secondary rays.

The third argument deals with the absorption of β rays by matter. The calculations appear to me to be concerned with scattering rather than absorption and to have little connection with the experimental facts from which the numerical data are derived.

3. It is possible that some estimate of the number of electrons in an atom can be obtained by consideration of the energy liberated in radioactive processes. According to the theory of radioactivity which seems to meet with general acceptance, the electrons in a radioactive atom are moving in closed orbits which are stable only in virtue of that motion. The radiation from the moving electrons decreases gradually their kinetic energy and their speed: the orbits cease to be stable, the electrons fall in towards the attracting centres, and the potential energy thus liberated appears as kinetic energy of the fragments of the atom ejected by the explosion. The energy liberated by a radium atom in its disintegration can be calculated from experiment: if we accept the view that this energy represents the potential energy of the electrons in their orbits, it will be only necessary to obtain some estimate of the average energy of an electron in order to ascertain the number of electrons in the radium atom.

4. Any such estimate of the average energy must be based upon assumptions that cannot be justified completely in the present state of our knowledge. I propose to assume that *the potential energy of an electron moving in a closed orbit, which is liberated when the orbit becomes unstable, is of the same order of magnitude as the maximum kinetic energy which the electron can possess without breaking free from that orbit.* This assumption is based on an analogy drawn from orbits described under the action of a central force varying inversely as the square of the distance from the centre: it is well known that the maximum kinetic energy, which a particle moving in a closed orbit under the action of such a force can possess, is equal to the kinetic energy which it would acquire in falling to its actual position from a place where its potential relative to the attracting centre is zero. It is not pretended that the assumption has more than a vague probability.

5. The greatest kinetic energy, which can be possessed by an electron moving *within* an atom, may be identified with some show of reason with the least kinetic energy which an electron moving *outside* an atom is found to possess. The slowest electrons which have been observed experimentally in a gas outside a radioactive substance are the δ rays discovered by Prof. Thomson: the speed of these rays has been measured by Ewers as

$$3{\cdot}25 \times 10^8 \text{ cm./sec.}$$

These electrons have doubtless lost some part of their energy in breaking away from the atom, but the energy spent in this process is known: it is the energy required to ionise a molecule. This energy is that acquired by an ion in falling through a potential difference of 20 volts, i.e. that possessed by an electron moving with the speed of 8×10^8 cm./sec.: it is of the same order as that possessed by the particles in the δ rays. Accordingly we shall take the value of the greatest kinetic energy which an electron can possess without breaking free from its orbit as twice that of a particle in the δ rays, i.e.

$$2 \times \tfrac{1}{2}\mu \times (3{\cdot}25 \times 10^8)^2 = 6{\cdot}7 \times 10^{-11} \text{ ergs},$$

where μ is the mass of an electron*. According to our assumption this quantity is also the potential energy of the electron in its orbit, which is liberated when the orbit becomes unstable.

6. This estimate of the average potential energy of an electron derives some support from theoretical considerations. If we suppose that the forces restraining the electron in its orbit are similar to those which would act on a small particle carrying the same charge as the electron and moving at the surface of a uniform sphere of electricity of radius a, the total charge in which is equal and opposite to that on the particle, the potential energy of the electron is

$$\frac{e^2}{2a} \text{ or } \tfrac{1}{2}\mu \times (1{\cdot}4 \times 10^8)^2,$$

If the radius of the sphere is identified with the conventional value for the radius of the atom, 10^{-8}cm. It may be objected that if there are N electrons in the atom the charge on the sphere will be $-Ne$ and not $-e$: but it must be remembered that the other electrons exert forces which tend to counterbalance that due to the charge on the sphere: it is probable that the resultant force is more nearly equal to that due to a total charge $-e$ than that due to a total charge $-Ne$.

* $\left(\frac{e}{\mu} = 1{\cdot}8 \times 10^7 \times 3 \times 10^{10},\ e = 3{\cdot}4 \times 10^{-10},\ \therefore \mu = 6{\cdot}3 \times 10^{-28}.\right)$

7. Taking the value of the average potential energy of an electron as $6{\cdot}7 \times 10^{-11}$ ergs, we may proceed to calculate the number of electrons in the radium atom. The energy liberated by one gram of radium throughout all its known radioactive changes is $1{\cdot}6 \times 10^{9}$ calories $= 6{\cdot}7 \times 10^{16}$ ergs. The atomic weight of radium is 225 and the mass of a hydrogen atom $1{\cdot}1 \times 10^{-24}$: therefore the energy liberated by a single radium atom is $1{\cdot}7 \times 10^{-5}$ ergs. Hence the value of N, the number of electrons in the radium atom, is given by

$$N \times 6{\cdot}7 \times 10^{-11} = 1{\cdot}7 \times 10^{-5},$$

$$\therefore\ N = 2{\cdot}5 \times 10^{5}.$$

If the mass of the radium atom is the sum of the masses of the contained electrons we must have

$$N = 225 \times \frac{M}{\mu}, \text{ where } M \text{ is mass of hydrogen atom}$$

$$= 4{\cdot}2 \times 10^{5}.$$

The assumptions that we have made lead to nearly the same value for N as the older assumption based on the mass of the atom. (It is perhaps pertinent to remark that the assumptions were made before the calculations and that they were not intentionally adopted to give the desired result.)

8. If, in place of the assumption of § 6, we assume that the force acting on any one electron is that due to the presence of a total charge $-Ne$ on the sphere in which the electron moves (where N is the number of electrons in the atom and e the charge on each), we shall obtain a minimum estimate of the N. For if our supposed constitution of the atom is at all near the truth, it is certain that the force acting on each electron and, therefore, its total energy, must be less than that given by this distribution. It will be found that the total energy (potential and kinetic) of the N electrons moving on the circumference of such a sphere of radius a is $N \times \frac{Ne^2}{a}$. Hence, if we put $a = 10^{-8}$, $e = 3{\cdot}4 \times 10^{-10}$, we have

$$N^2 \frac{(3{\cdot}4 \times 10^{-10})^2}{10^{-8}} = 1{\cdot}7 \times 10^{-5};$$

$$\therefore\ N = 1200.$$

It should be observed that such an atom must lose its *whole* energy in providing the energy liberated in radioactive processes: the system resulting from the disintegration would possess no internal energy. Whereas, according to the view which was taken in § 6, the redistribution of the electrons in stable orbits after the

explosion might leave each of the remaining electrons with the same energy as it possessed before the disintegration: the energy of the system would merely decrease in the same ratio as the number of the electrons in it.

Accordingly we may conclude that if our hypothetical structure of the atom—electrons moving in a sphere of positive electricity—is at all near the truth, the number of electrons in a radium atom must be greater, and probably very much greater, than 1200.

It is possible, indeed probable, that this structure of the atom is not at all near the truth: that greater complexity will have to be attributed to the positive portion of the atom and that some of the energy of radioactivity may be derived from a change in the constitution of this part of the atom. But even if a fundamental reconstruction of our notions of the atom should be found necessary, the considerations that have been advanced may be of some service in drawing attention to features that must be taken into account by all designers of model atoms.

Notes on the Structure and Behaviour of the Larva of Anopheles maculipennis, *Meigen.* (Preliminary note.) By A. D. Imms, B.A., Christ's College. (Communicated by Mr A. E. Shipley.)

[Read 11 February 1907.]

The larvæ of this Mosquito were collected in the neighbourhood of Cambridge during the year 1906. They were met with on various dates ranging from May 9th up to August 10th, and were obtained from the following four localities: (1) A small bricked excavation in the middle of a field, measuring one and half feet in cubical dimensions. In addition to larvæ of *Anopheles*, the water contained *Cyclops*, green larvæ of *Chironomus*, a few small Coleoptera and confervoid Algæ. (2) A roadside pond partly covered with *Lemna*, and containing great numbers of Ostracoda, together with red larvæ of *Chironomus*. (3) Still places in the backwaters of the Cam. (4) Two ponds situated in a field. In one of them they were met with in company with larvæ of *Dixa*, *Chironomus*, and of an undetermined species of Psychodidæ. The pond also contained numerous dragon-fly larvæ belonging to several species, together with may-fly larvæ and a number of small fish (measuring up to about eight inches in length). In the other pond there were no fish but great numbers of dragon-fly and may-fly larvæ, and also larvæ of the Stratiomyid fly *Odontomyia*.

The *Anopheles* larvæ were scarce during the whole period, and although they were sought for elsewhere none were discovered in any other localities around Cambridge.

An account was also given of the general features of the external structure of the larva together with some remarks on the habits and behaviour of the animal. The remainder of the paper dealt with the internal anatomy of the larva.

The integument consists of a chitinous cuticle and, underlying it, the hypodermis or chitogenous layer. The cuticle is smooth and transparent and consists of two layers: an outer and much thinner but highly refractive layer, and a relatively thick inner stratum, which is much softer and apparently only partially chitinised. The hypodermis consists of a single layer of cells resting internally on a delicate basement membrane. There occurs in many places immediately beneath the hypodermis, and adherent to its inner surface, a layer of flattened, irregularly shaped cells—the sub-hypodermal cells of Viallanes.

The mouth-parts together enclose a space or chamber, at the posterior end of which is situated the mouth itself. The epipharynx forms the roof of this chamber, the mandibles form the sides, and the maxillæ, together with the labial plate, the floor. The fore-gut is divisible into pharynx and œsophagus. An elaborate pharyngeal musculature was described, and the author believed that it is principally concerned with the process of swallowing. The œsophagus is prolonged backwards into the cavity of the mesenteron in the form of an œsophageal valve and a circular blood sinus is present in relation with the latter. The mesenteron consists of a cardia or outer wall enclosing the œsophageal valve, a ring of eight cœca, and the stomach. A peritrophic membrane is present and its seat of origin is believed to lie in a special area of greatly enlarged gland cells, which are situated at the commencement of the mesenteron.

The hind-gut is divisible into three regions, viz. ileum, colon and rectum, and the ileum receives at its commencement five malpighian tubes.

The respiratory organs consist of the tracheal system, and possibly of the two pairs of anal processes situated around the hinder extremity of the body, which may be of the nature of gills. The tracheal system communicates with the atmosphere by means of a single pair of spiracles located on the dorsal aspect of the eighth abdominal segment. It is, therefore, an example of the metapneustic arrangement. There are two principal longitudinal trunks, lying one on either side of the mid-dorsal line of the body. These vessels run from the spiracles directly forwards into the thorax. In the latter region each trunk divides into a pair of branches which supply the various organs of the head: and in the abdomen the branches of the tracheal system maintain to a large extent a segmental arrangement. In the region of the eighth abdominal segment the two main trunks give off a great number of small branches along their inner and ventral aspects. These branches pass to the wall of the terminal chamber of the heart and, on account of the thinness of the walls of their ultimate capillaries, it seems very probable that by this means the blood is brought into close contact with the oxygen contained in them, and in this way a kind of "lung" is formed. A similar arrangement was found to occur in the larvæ of *Dixa* and *Culex*, and reasons were given which suggest that it may be correlated with a metapneustic tracheal system.

The anal gills consist of two pairs of delicate leaf-like outgrowths of the integument situated around the anus. The cavities of the gills are in free communication with the general hæmocœlic cavity of the animal and contain, in addition to blood, fine tracheal branches. They are invested with a very thin integu-

ment and it is probable that they function as accessory respiratory organs.

The heart is a muscular tube which extends from the posterior margin of the eighth abdominal segment and passes forwards through the thorax into the head where it terminates in the neighbourhood of the brain. In the region of the abdomen it consists of a series of consecutive chambers each being provided with a pair of lateral ostia or inlets and associated with the latter are the alary muscles. In the thorax the heart is much reduced in diameter, there being no alary muscles, and it forms a narrow well-defined tube which is usually termed in Insects the aorta. The latter extends forwards through the occipital foramen, and becomes enclosed just behind the brain in an irregular mass of tissue, which forms a kind of supporting collar or "anneau de soutien."

The nervous system consists of the brain or cerebral ganglia and a ventral nerve chain of twelve ganglia. The latter comprise the sub-œsophageal ganglion, three thoracic ganglia and a series of eight ganglia to the abdomen. The ganglia of the last two segments are fused together into a ganglionic mass situated in the eighth abdominal segment.

The muscular system was dealt with in some detail and special attention was given to the jaw muscles, the muscles of the spiracular skeleton and those of the ventral tail fin.

The fat body is almost entirely confined to the thorax and the first seven abdominal segments. It consists of a parietal layer situated just beneath the integument, a visceral layer lining the body cavity and lying between the longitudinal muscles and the gut-wall, and a peritracheal layer which invests some of the principal tracheal trunks. The limits of distribution of each of these divisions vary according to the age of the larvæ, and a certain amount of individual variation is also noticeable among specimens of as nearly as possible the same age.

Œnocytes are present and well developed, and belong to two varieties the large and the small. The large œnocytes are segmentally arranged in clusters, and are present in each of the first seven abdominal segments, but were not observed in the eighth or ninth segments, and are likewise absent from the thorax. The small œnocytes are very numerous and, moreover, have no definite arrangement. They occur just beneath the hypodermis in the neighbourhood of each group of the larger œnocytes and are mainly situated anterior to the latter, but they also occur in some numbers along the floor of each segment, on either side of the nerve cord. They occur in the first seven segments, a few are also present in the eighth, but none were to be discovered in the last segment. The imaginal buds are well developed and

easy to discover. They are superficial in position, being situated just below the hypodermis, and the primitive invaginations of the buds remain permanently open.

The antennal buds are the largest of the cephalic buds and are placed at the bases of the larval antennæ, but are in no way enclosed by the latter. The buds of the future labrum, labium and maxillary palpi alone attain the condition of imaginal folds prior to pupation; those of the mandibles and maxillæ remain in the condition of simple hypodermic thickenings. In the thorax three successive pairs of buds are present on either side, belonging to the pro-, meso-, and meta-thorax respectively and disposed in a dorsal and ventral series. The ventral row give rise to the three pairs of legs, while of the dorsal series, the first pair form the pupal respiratory siphons, the second pair the future wings and the third pair the halteres.

The imaginal buds of the abdomen consist of a dorsal and ventral pair situated on either side near the hinder extremity of the body. The dorsal pair of buds form the pupal tail fins, they are placed one on either side of the eighth abdominal segment and lie within the supporting skeleton of the larval spiracles. The second pair of buds are ventral in position and are destined to form the gonopophyses or accessory copulatory organs of the imago.

The remainder of the paper dealt with the general structure of the larvæ of the various genera of the Culicidæ together with remarks on their mutual affinities.

The first part of the paper has been published in the *Journal of Hygiene*, Vol. VII. No. 2, April, 1907, and the remainder is in course of publication in that same periodical.

Physiology of Plants in the Tropics. By A. M. Smith, B.A., Emmanuel College. (Communicated by Mr F. F. Blackman.)

[*Read* 20 May 1907.]

(α) *The Internal Temperature of Leaves under Tropical Insolation.*

The temperature was obtained by a thermo-electric apparatus reading to ·5° C.

In still air, with Black Bulb Vacuum Thermometer at from 55°—62° C., the air temperature in the shade being from 25°—28° C. and the humidity about 70 %, leaves whether thick and fleshy (*Tradescantia discolor*) or thinner and somewhat coriaceous *Magnolia* sp., *Amherstia nobilis*) or quite thin and pliable (*Acalypha* sp.), when placed normal to the sun's rays, reach a temperature of 15° C. above the surrounding air, i.e. 40°—43° C., a temperature hitherto often considered injurious to the functions carried on in the leaf.

In the shade the internal temperature varies from 1·5° below to 4° above that of the surrounding air under different conditions. Of factors tending to reduce this high temperature the movement of the air is the most important. Breezes of various strengths reduced the temperature in the sun by amounts varying from 2°—10° C.

An attempt was made to estimate the magnitude of the cooling due to transpiration. Two leaves with stomata outwards were consistently lower in temperature than two with their stomatal surfaces facing each other. The difference was on an average 2·5° C.

Investigations into leaves with red or red-brown colouring matters showed that the red pigment raised the internal temperature of the leaf from 2°—4° C. above similar leaves which were white or nearly so.

Young coloured leaves of thin texture would probably be cooler than mature green leaves of the same species owing to more rapid loss of water. The presence of the red pigment, however, causes their temperature to be almost equal to or even higher than that of the mature leaf in different cases.

(β) *Periodicity of growth in Ceylon.*

Monthly observations on the time of growth of certain evergreen trees with young foliage coloured red or brown showed

hat there was the largest amount of young growth in February, he driest month of the year. The theory is suggested that only hen is there sufficient transpiration to supply the necessary nineral food for rapid growth. The greater transpiration roduced by the higher temperature of the young leaves owing o their red colour would assist in obtaining this mineral food upply.

γ) *Respiration of Hydrilla verticillata, a tropical water-weed.*

Values for the respiration from 7°—50° C. were obtained, n each case within two hours from the beginning of the xperiment. These when plotted produce a curve which hows increase of respiration with temperature according to he Van t' Hoff rule, the coefficient for an increase of 10° C. eing 2·2. The values go on increasing up to the death-point f the plant.

Notes on the parasitism of Botrytis. By F. T. Brooks, B.A., Gonville and Caius College. (Communicated by Mr F. F. Blackman.)

[*Read* 20 May 1907.]

The conidia of Botrytis are unable to infect healthy green leaves, whereas if a young mycelium, nourished saprophytically, is placed upon a normal leaf of such a plant as Lettuce, infection rapidly spreads.

Experiments have been undertaken to ascertain whether the conidia can cause the infection of plants weakened in various ways. Lettuce plants were grown in sterilised sand which was watered from time to time with different mineral solutions. One group of plants was watered with a solution containing the elements essential to ordinary plant life, while the other groups were watered with solutions containing no nitrogen, phosphorus, potassium and magnesium, respectively. After these plants had been growing six weeks the conidia had no power of infecting them.

On the other hand it was found that by tearing healthy green leaves of Lettuce plants direct infection was caused by placing the spores upon the torn portion. The conidia are able also to infect leaves just beginning to turn yellow—whether this yellowing occurs in ordinary light or after placing the plants in darkness.

The histology of the early placenta of Macacus nemestrinus.
By W. L. H. Duckworth, M.D., Sc.D., Jesus College, University Lecturer in Physical Anthropology.

[*Read* 25 February 1907.]

Among the numerous specimens presented to the Anatomical Department by Dr C. Hose is the uterus of a female Macacus nemestrinus monkey from Sarawak, Borneo. The anterior uterine wall had been cut into, and when the posterior wall of the uterus was exposed, a small hemispherical projection was noticed springing from the upper portion. In general appearance, the uterus closely resembled the uterus of a female "Lutung" monkey (Semnopithecus pruinosus) drawn and described by Selenka in 1901*: and again there was a distinct resemblance to a similar specimen (but of Semnopithecus nasicus) also figured by Selenka in 1900†.

The present example appeared rather smaller than those represented by Selenka, and in equatorial diameter measured 2·2 mm. only.

This projecting mass with a block of the subjacent uterine tissue was stained in bulk (in carmine) and cut serially into 520 sections, some of which were afterwards counterstained with eosin.

Figs 1 and 2 represent sections 117 and 295 respectively, and shew that the uterus was undoubtedly pregnant but that a part only of the blastocyst remains, viz. that portion which has contracted an attachment to the uterine wall. The embryo itself has fallen out.

The extreme rarity of specimens illustrating the events occurring in the earliest stages of placental development in the apes and man, justifies a careful study of the specimen in spite of the imperfection alluded to; and the following account contains a resumé of the observations which have been made.

The orientation of the specimen will perhaps be understood better when the sections represented in Figs. 1 and 2 are compared with Fig. 3 (q. v.). The latter represents the specimen in relation to the general uterine surroundings, viz. the wall of the uterus and the uterine cavity. The parts no longer present have been added in a schematic manner, but it is believed that the representation is fairly correct.

* Selenka: "Placentaranlage des Lutung," *Münchener. Sitz. der math.-phys. cl. der Kgl. bayr. Akad. der Wissensch.* 1901, Heft 1. Tafel 1. Fig. 1.

† Selenka: *Studien über die Entwickelungsgeschichte der Thiere*, 8tes Heft, 1900, Fig. 25.

It appears then that the adherent part of the wall of a blastocyst is retained in the sections, and even the low power drawings (Figs. 1 and 2) reveal the presence of villous processes. Higher magnification shews that mesoderm has not yet reached the great majority of these villi, and the inference is to the effect that the stage is an extremely early one, possibly as early as the middle of the first week of development.

In specimens of this kind particular attention is directed to the following features, and these are dealt with briefly in the sequel.

(1) The implantation of the blastocyst in the uterine wall*.

(2) The changes in the uterine wall determined by the arrival of the blastocyst†.

(3) The history and changes of the embryonic tissues subsequent to the attachment of the blastocyst: with special reference to:

(*a*)‡ The mode of communication whereby the maternal

* The mode of implantation of the blastocyst is well known to vary in the several Orders of Mammalia. The literature upon this subject is extensive, but has been admirably reviewed by Mr Assheton, *Phil. Trans. Roy. Soc. London*, Series B, Vol. 198, pp. 143--220, "The morphology of the Ungulate Placenta," 1906, and by Dr A. Robinson in the Hunterian Lectures, 1903 (published in the *Journal of Anatomy and Physiology*, Vol. xxxviii.).

Selenka (*op. cit. supra*) has demonstrated the mode of attachment which obtains in animals of the genera Semnopithecus and Hylobates among the higher Primates.

Peters ("Uber die Einbettung des menschlichen Eies &c." *Deuticke*, Leipzig, 1899), has clearly described the appearances and surroundings of an early human ovum, and demonstrated the apparent resemblance of the processes herein to those shewn by Graf. v. Spee (full references in Hertwig's *Handbuch der vergleichenden und Experimentellen Entwickelungsgeschichte der Thiere*, Band II. p. 366, and also p. 342) to obtain in the Guinea-pig.

Other classical accounts are reviewed and criticised by Strahl in Hertwig's *Handbuch* (p. 342).

Siegenbeek van Heukelom's research will be particularly mentioned in the sequel. The original account is in the *Archiv für Anatomie und Physiologie*, Anatomischer Theil, 1898.

Frassi has quite recently published a description of the appearances of a human embryo (in utero) of the age of ten days: *Archiv für Mikroskopische Anatomie und Entwicklungsgeschichte*, 1907, Band 70, Drittes Heft.

† In monkeys of the family Cercopithecidae, the *decidua capsularis* is not found. The uterine surface is described by Selenka ("Placentaranlage &c." p. 7) as raised into a wall or circumvallation around the blastocyst. The uterine tissues become oedematous. The uterine glands are represented (*Studien* Taf. II. Fig. A) as somewhat dilated at their mouths. "Cell-nests" derived from uterine epithelial cell-elements are believed by Selenka to become transformed into "syncytia" which in turn embrace the ends of the embryonic villous processes. Reference should also be made to Strahl in Hertwig's *Handbuch*, Band II. pp. 326 *et seq.* For the comparative study in different mammalian Orders, Strahl's work must be consulted, and also the memoirs of Assheton and of Robinson (*op. cit.*).

‡ In this connexion, reference is necessary to the literature dealing with the formation and the nature of the walls of the intervillous spaces. Again Strahl's memoirs and his contribution to Hertwig's *Handbuch*, Vol. II. must be mentioned. Voigt (for references *v. infra*) has also lately published a valuable paper on this subject.

blood passes from the uterine capillary vessels to the intervillous spaces.

(*b*)* The relation of the embryonic tissues to the uterine glands.

(*c*)† The nature of the embryonic cells involved in the preceding processes (*a*) and (*b*).

(1) *The implantation of the blastocyst in the uterine wall.*

The first point to notice is that the blastocyst is implanted upon the uterine surface without having sunk into the substance of the uterine wall. The blastocyst is not received into a crypt or an enlarged glandular orifice. Herein, the present specimen corroborates the observations of Selenka upon the blastocysts (in similar early stages) of Semnopithecus (pruinosus and nasicus), so that these primate forms differ from man. In the latter, the observations of Peters (*op. cit.*) shew that the blastocyst does not remain upon the surface. In Macacus nemestrinus and the Semnopitheci, a primary placenta is formed at the first site of attachment, but as the blastocyst expands, it comes into contact at its opposite pole with the opposed wall of the uterus, and here a secondary placenta is formed. In this way the twin placental discs of these monkeys arise. As regards the details of this process, it appears to me justifiable to presume that in the present specimen the extent of the primary attachment is less than it will subsequently become. And therefore it can be inferred that if the sections are studied serially, the events occurring in the more peripheral sections will successively reproduce those which took place while the more central parts of the blastocyst were contracting the relations they now bear to the maternal tissues‡.

* Siegenbeek van Heukelom (*Archiv für Anatomie und Physiologie*, Anat. Theil, 1898, p. 12) describes with some minuteness the conditions of the uterine glands at a very early stage in the formation of the human placenta. No traces of degeneration in the glandular epithelium were seen. Nor was there evidence of the transformation of such epithelium into a syncytial mass. Some glands contained blood and this was regarded by Siegenbeek van Heukelom as suggestive of pathological change. But the occurrence in a wild animal (in its natural surroundings) such as that which furnished the present specimen, indicates that haemorrhagic invasion of the glands may occur in any case, and to this view Siegenbeek van Heukelom evidently inclines (*op. cit.* p. 12).

The same writer declares that the epithelium of the uterine glands disappears, and takes no important part in the process of placental formation.

† An excellent resumé of the literature relating to the nature of the embryonic cells involved in early placental formation is provided by Strahl in Hertwig's *Handbuch*, pp. 337 *et seq.* Robinson's lectures may also be mentioned, as well as Voigt's instructive papers (for reference to which *v. infra*).

‡ The allowance to be made for the flattening out of the previously spherical blastocyst in the processes of fixing, hardening, embedding and cutting has not been overlooked.

Now through many sections (45 in number) the uterine epithelium beneath the blastocyst remains intact. Such a condition is clearly shewn in Fig. 4 representing section No. 45.

In this section (Fig. 4), the coast-line, so to speak, of the uterus is still clothed with epithelial cells, and the blastocyst is still some distance away, looking like a number of islands separated from the coast by a channel.

But already the effect of the presence of the blastocyst is being felt by the uterine tissues. In the sections, only the so-called Decidua compacta is shewn, and in this much oedema is present. In places in the submucous layer, fibrinous exudation is clearly seen (Fig. 4) and as the sections are followed towards the more central region, the exudation increases and eventually the tension is sufficient to lift the epithelial layer off in strips. The process is exactly comparable to that which follows when in acute inflammation a submucous surface is denuded while the cast-off epithelium with detritus and leucocytes forms a so-called "false membrane."

By the time this removal has taken place, the blastocyst wall is in close apposition with the tissue removed, and the blastocyst may very possibly have played a more direct part in its removal, than the indirect action it exerts by causing the inflammatory exudation. But the appearances seem to fully justify the preceding description.

I must guard this description however from the possible inference that the blastocyst is actually attached first to an area denuded of uterine epithelium. Most probably at the first moment of contact, the epithelial layer is just becoming detached as described.

The detached cells then disappear, and seem to be destroyed partly by extravasated blood-cells, but also possibly by the embryonic cells now close upon them.

In two or three sections (46, 47, 48) there are suggestions of some proliferation of the uterine epithelial cells over a very small extent of surface, but the cells thus characterised cannot be traced into contact with any other cells on their exposed aspect, and seem rather to be degenerating than increasing. But this occurrence demands special mention, for otherwise the very definite statements of Selenka concerning the increase and proliferation of the uterine epithelial cells would find absolutely no support at all from the present observations. These remarks on the appearances of the uterine wall naturally lead to the next division of the subject which will be now considered.

(2) *The changes in the uterine wall determined by the arrival of the blastocyst.*

As already remarked, the block of tissue removed with the fragmentary blastocyst consists entirely of decidua compacta. Some of the changes herein have been already noticed (cf. (1) *supra*). Thus the general appearances are best compared to those attendant upon an inflammatory process.

The decidua compacta is composed of "stroma cells" in the interstices of which widespread oedema has occurred. The capillary vessels do not appear unusually numerous or large however. The exudation is most marked in the tissues immediately underlying the surface epithelium, and at this level the exudation is so plentiful as to form distinct patches (cf. Fig. 4). In these patches there are not many leucocytes, and the exudation appears to be coagulated, owing no doubt to the action of the fixing reagent.

The stroma cells give no clear evidence of proliferation and increase, save in some of the more central sections, and then the appearance is very local.

The glands are not remarkable for tortuosity, but some distinctly shew enlargement towards their mouths. Into some of the glands, as will be shewn in the sequel, haemorrhage has taken place and then the epithelial lining cells tend to degenerate and to disappear*.

I have not been able to identify the cell-nests described by Selenka† and referred by that author to proliferating uterine epithelial cells.

In the more central sections, the blastocyst and uterine wall are firmly coherent. Here one can distinguish regions which are either indubitably embryonic or maternal respectively, and between these comes an intermediate area wherein the constituent cells appear at first sight to be inextricably confused and intermingled (Figs. 5 and 6). This intermediate area, shewn better in Fig. 6, (the "Placentar-polster" of Selenka) is characterised on the maternal aspect in the following way. First the stroma cells tend to separate and thus wider intercellular spaces are left. The capillary vessels become more distinct being more fully distended than elsewhere. Extravasation of red-blood cells occurs and these are found (cf. Fig. 5) making their way towards the embryonic tissues. Rarely, larger arterial capillaries or arterioles of spiral form are cut, and there is some evidence that the glands tend to assume a slightly spiral course.

* This agrees with the description provided by Frassi (*op. cit.*).

† *Placentaranlage*, p. 7.

On the embryonic side, the villous processes have united to some extent, forming an irregular plateau of ectoblast (trophoblast) like that described by Siegenbeek van Heukelom (*op. cit.*) in the human ovum. These embryonic villous processes can be traced far into the "placentar-polster" and in some sections (cf. Figs. 7—11) embryonic tissues invade dilated maternal capillary vessels, and also maternal glands, as will be described in the sequel.

(3) (*a*) *The mode of communication whereby the maternal blood passes from the uterine capillaries to the intervillous spaces.*

As one traces the sections serially from the periphery inwards, evidence is soon obtained of the passage of red-blood corpuscles into the interstices of the stroma cells. This is represented in Fig. 5 which shews the conditions observed in the 134th section. In this section some dilation of the uterine capillaries can be seen and the dilation is more evident as the centre of the area of attachment is approached. Fig. 6 representing section 266 serves to illustrate this point. Thus red-blood corpuscles may reach the intervillous spaces after a longer or shorter course, but where only a few escape at a time and wander among uterine and embryonic cells, it is by no means improbable that they run the risk of destruction before the villi are reached. The appearances observed under a higher power than that employed for the representations in Figs. 5 and 6, are seen in Figs. 7 and 8 (taken from sections 266 and 274).

In each of the latter, a capillary vessel is shewn stretching across the figure and the blood stream divides to embrace with two side-channels a mass of tissue which I submit to be almost wholly embryonic in origin.

The endothelial cells lining the capillary vessel are traceable up to a certain point only. Beyond this they are lost and the blood thenceforward bathes the embryonic tissues directly. The blood thus travels to the intervillous spaces, which must therefore be regarded as bounded by embryonic cells. Upon this subject very different opinions have been expressed. Strahl in Hertwig's *Handbuch*, Vol. II., pp. 337, 338, distinguishes five distinct views. The present description accords most closely with that placed third in the list by Strahl and held by such authors as Farre, Kölliker, Langhans and Heinz. To these, the name of Siegenbeek van Heukelom may be added.

There is no evidence of proliferation of the endothelial cells to provide a lining for the intervillous spaces.

As to the mode of destruction of the capillary wall, one must be guarded. Externally the stroma soon becomes less dense, the constituent cells become more widely separated as the limits of

the definitely uterine tissue are approached. The continuity of the lining of the capillary tube is broken even before the endothelial cells finally disappear, and red-blood corpuscles are found outside the tube (see especially in Fig. 7) and in the interstices of the uterine cells.

Peripherally, the embryonic tissues appear to invade the capillary vessel, perhaps even to press its wall inwards before destroying its continuity. But the embryonic cells are themselves liable to suffer from this contact. The frayed-out appearance of the tissue attached to the embryonic mass in Fig. 8 especially ("*f*") indicates that some sort of conflict has taken place. Isolated strips of such frayed-out material within some of the capillary vessels suggest the invasion of the latter by detached masses of embryonic origin. Such an invasion has been definitely described by Siegenbeek van Heukelom (for the human ovum), but the appearances in the present instance do not warrant an equal definiteness in description.

(3) (*b*) *The relation of the embryonic tissues to the uterine glands*, is shewn in Figs. 9, 10, 11. These represent three sections (viz. Nos. 263, 265, 267) in which a mass of embryonic cells was observed invading a tubular gland into which haemorrhage had taken place. The lining epithelium of the gland has disappeared and it is hard to recognise with certainty even degenerating remnants of the epithelial cells. Around the gland, as its mouth is approached, the uterine stroma becomes less dense, and the open mesh-work thus produced resembles that surrounding the capillary vessels at their peripheral ends.

My interpretation of Figs. 9, 10, 11 is that a rounded mass of embryonic cells has approached the peripheral end of the gland obliquely. As this approach progresses, the tissue becomes rarefied in density. Destruction of the uterine stroma cells is thus strongly suggested, but whether the active agents in this destruction are cells, or enzyme-like fluids produced by the embryonic or other tissues, it is not possible to say. Leucocytes are not abundant, and of such as are seen, the majority are characterised by the peculiar division of the nuclei into tetrads, similar to those seen by Selenka*, and Siegenbeek van Heukelom†. Some of these remarkable cells are found, as shewn in Figs. 10 and 11, in the closest relation to or even within the embryonic tissues. The appearances thus indicate a process of invasion wherein the embryonic cells play an active part. The process resembles that already seen in connexion with the capillary vessels, so that the activity of the embryonic

* *Studien*, 8tes Heft, Taf. II. Fig. E, "L."
† *Archiv für Anatomie*, 1898, Taf. I.

tissues is as strongly suggested here as in the classical examples described by Siegenbeek van Heukelom and others.

I am not able to adduce evidence in support of the very definite observations made by Frassi (*op. cit.*) as to the clear communication between the lumina of the glands and the intervillous space. It must be remembered, however, that Frassi describes an early human embryo. In the present example of Macacus nemestrinus, several sections (perhaps especially No. 209) shew that the glands extend nearly to the intervillous space. But the glandular epithelium is in these instances degenerating, and in other cases such as the sections 244 (and those immediately following this), 260, 263—267 (described above) and 317, the mouth of the gland appears to be invaded by embryonic tissues. The latter may very probably subsist upon the haemorrhagic contents of some of the glands, as suggested by Frassi. The latter author suggests that the presence of leucocytes provides a good criterion of maternal tissues as contrasted with those of embryonic origin, but my observations lend little support to this, though I prefer not to lay stress upon the subject till I have carefully revised the preparations here described.

(3) (*c*) *The nature of the embryonic cells concerned in the preceding descriptions,* 3 (*a*) *and* 3 (*b*).

The embryonic cells which come into relation with the maternal capillary vessels and glands, are so far as can be judged, continuous with those of the villous processes. It is hard to find in the distinctly maternal tissues any isolated masses of cells which can be pronounced unhesitatingly to be embryonic intruders, though cell-groups of suspicious appearance occur.

Of the villous processes, some are short and project freely into the intervillous spaces. Others are longer, and their "maternal" extremities are not free but appear as though expanded laterally so far as to fuse with each other. From this fusion results the mass of embryonic tissues which is in immediate relation with the uterine wall. Siegenbeek van Heukelom (supported by Hubrecht and Peters) has suggested another explanation of these appearances. He supposes that the intervillous spaces are not situated between processes which originally projected as villi from the blastocyst. But instead, he offers the explanation that the intervillous spaces really arise as clefts in a continuous mass of thickened trophoblast. Whichever view may be correct cannot be decided by the specimen now described, but in any case we must distinguish the shorter indubitable villi projecting into (and ending in) the intervillous spaces, from the longer, larger processes which form the boundaries of those spaces; the latter are the "balken" described by Siegenbeek van Heukelom, and in fact

constitute a series of bridges between the proximal and distal parts of the trophoblast. As has been noted already, hardly any of these villi contain a mesodermal core. They are solid columns of cells, and the appearances of these columns in section are represented in Fig. 12. Two varieties of tissue are present. Internally, large clear cells with large clear nuclei are seen (Voigt's "Grundschicht"). Around these a layer of protoplasm is wrapped. This layer stains more deeply than the central cells from which it is thus easily distinguishable. In its substance nuclei of elongated form are seen at intervals ("Deckschicht" of Voigt).

It is tempting to regard the inner clear cells as those of Langhans' layer (the term "layer" is applicable only after mesoblastic tissue has penetrated the previously solid rod or column of epiblastic cells), while the outer layer would then represent the 'Syncytium."

But while doing so, certain objections must be recognised. For the central cells do not in appearance reproduce those represented in the corresponding position in Selenka's most elaborate drawing*. In fact as regards the relative sizes of the nuclei, the conditions in my specimen are exactly the reverse of those depicted by Selenka. It occurs to me that the drawing referred to is too diagrammatic, and in fact I believe this criticism has already been made.

Again, I have no evidence of cell-nests first seen in the submucosa in stages of transition suggesting the origin of this darkly stained covering to the villi. But the ground is open to criticism, and the origin of the syncytial layer from uterine epithelial cells as described by Selenka† is not proved beyond doubt for the monkey, whatever may be the case in the rabbit.

The outer layer is discontinuous and in places is detached from the underlying cells. In certain sections (cf. especially Fig. 8 *f*" and section 262) strips of it seem to be found in the path of the red-blood cells as they enter the intervillous spaces‡. (This is particularly well shewn again in section 341.) But it seems to be diminishing in importance, while the inner cells of the villi are augmenting in volume and these eventually bound those parts of the intervillous space which are in direct continuity with the opened-up capillaries (Figs. 7 and 8).

It must be admitted that the appearance of what is here identified with the syncytial covering of the villi, does not bear out the very definite account and drawings of Selenka ("Placentaranlage"). But on the other hand, some features of the syncytial

* *Studien*, 8tes Heft, p. 190, Taf. II. Fig. A.

† *Placentaranlage*, p. 7, 1901.

‡ Syncytial tissue in such situations was observed by Siegenbeek van Heukelom, who suggests that they may be amoeboid (*op. cit.* p. 25).

layer as described by Siegenbeek van Heukelom are found herein. Moreover the view here expressed as to the identity of the several elements is in accord with the description of the corresponding features in early human placentæ as provided by Voigt*.

And lastly, in the Figures 9, 10, 11, the mass of embryonic tissue described as invading the lumen of the blocked-up uterine gland, resembles this outer layer, in its staining qualities, so that they may be regarded as identical. And it is probably on account of the greater mass of the tissue seen in the Figures (9—11) that the nuclei are so much more distinct here than in those regions in which the layer is attenuated.

Conclusions.

1. The specimen represents the histological conditions in an early stage of placental formation in Macacus nemestrinus.

2. The decidual formation is that known as decidua compacta basalis, no decidua reflexa being present. The "wall" or circumvallation described by Selenka in Semnopithecidae is not present here.

3. The uterine tissues immediately beneath the area of attachment of the blastocyst, and also for some distance on either side of this, are oedematous.

4. Immediately beneath the blastocyst, there is even an accumulation of a fibrinous exudation, by which the apparently degenerating cells of the uterine epithelium are thrust off. These cells are then probably destroyed, whether by the action of the embryonic ectodermal cells, or by that of leucocytes escaping with the fibrinous exudation, or by both methods, cannot be ascertained.

5. There is no evidence of the transformation of cells either of the uterine epithelium or of the glandular lining, into syncytial masses, as described by Selenka in Semnopithecus pruinosus &c., and by Langhans and Merttens in man.

6. The cell-nests found by Selenka in the submucosa in the animals mentioned above, cannot be identified with certainty and are not in any case prominent objects.

7. The evidence of the sections leads to the conclusion that the intervillous spaces are not lined by any derivatives of maternal cells, but by embryonic ectodermal cells.

8. The epithelial lining cells of the uterine glands seem to play no permanent part in the formation of placental tissues.

* *Zeitschrift für Geburtshilfe und Gynäkologie*, Band 54, 1905, pp. 66, 67. Cf. also Voigt, *ibid.* Band 51, 1904.

Before they meet any embryonic tissues, the gland cells may be largely destroyed through haemorrhage into the gland-cavity or lumen. When the glandular epithelial cells do meet the embryonic cells, they seem to be destroyed while the latter persist.

9. Two varieties of embryonic ectodermal tissue take part in these processes. They are (i) the outer, more deeply stained and in places discontinuous masses, identified in the description with the syncytial tissue (Plasmoditrophoblast of the writers on this subject): and this tissue does not seem to play a permanent part in the placental formation, though it may invade capillary vessels and uterine glands. It seems to determine the opening up of communications between the maternal capillary vessels and the intervillous spaces. (ii) The other tissue is identified with Voigt's Grundschicht of the villous processes (? Cytotrophoblast of other authors) and this is the tissue which has permanent relations in the placenta as ultimately constituted.

10. The absence of mesodermal tissues (embryonic) from the villi indicates the early stage of development here described. At the same time, this absence renders difficult the identification of various tissues in the embryonic villi.

DESCRIPTIVE NOTES TO FIGURES.

Fig. 1. Section 116 (× 16). The remaining portions of the blastocyst project from the uterine wall into the uterine cavity. Villi and intervillous spaces are shewn.

Fig. 2. Section 293 (× 16). The general appearances resemble those in Fig. 1. Here a more distinct placental area is seen. The glands are rather more numerous.

Fig. 3. This is a schematic representation of the probable conditions obtaining in the specimen before part of the blastocyst had been removed. The latter structure projects into the uterine cavity. The thick trophoblastic layer is shewn. The figure is based upon those provided by Selenka (for references cf. text).

Fig. 4. Section 45. Obj. $\frac{2}{3}$. Oc. No. 2 (× 4). Camera lucida, Leitz. The blastocyst is not here actually attached to the uterine wall over which the epithelium still forms a continuous covering. The uterine tissue is oedematous, and in places a fibrinous exudation has been poured out beneath the epithelium.

Fig. 5. Section 134. Obj. $\frac{2}{3}$. Oc. No. 2 (× 4). Camera lucida, Leitz. The blastocyst is now seen in intimate contact with the maternal tissues. Special attention is directed to the positions occupied by red blood corpuscles which in many instances are situated among the cellular elements, and are not confined to the capillary vessels.

a. red blood-cells extravasated.
b. red blood-cells between uterus and blastocyst.
c. capillary vessel.
d. villus (this corresponds to the "balken" of some writers).
e. embryonic mesoderm.
f. portion of a villus in contact with uterine tissues.
g. cells apparently derived from uterine epithelium, and possibly proliferating.
h. uterine gland with somewhat dilated lumen.
i. fibrinous intercellular exudation.
j. fibrin-mass, possibly in a capillary vessel.

Fig. 6. Section 266. Obj. $\frac{2}{3}$. Oc. 2 (× 4). Camera lucida, Leitz. The entry of the blood into an intervillous space can be traced here. A large gland is seen filled with red blood-cells, and into its distal end projects a mass of embryonic tissue.

a. embryonic villus (ectoderm).
b. embryonic mesoderm.
c. red blood-cells extravasated.
d. red blood-cells in an intervillous space.
e. red blood-cells entering an intervillous space.
f. embryonic tissue invading a gland (cf. Figs. 9, 10, 11).
g. haemorrhage in the lumen of the gland.
h. a gland traceable towards the intervillous spaces.
i. a dilated capillary vessel.
j. red blood-cells in a capillary vessel.

Fig. 7. Section 266. Obj. Zeiss D. Oc. 2 (× 4). Enlarged view of the capillary vessel shewn in the centre of Fig. 6 (*i*). The capillary wall is interrupted by intruding cells from embryonic tissues. No proliferation is seen in the endothelial cells lining the capillary. Red blood-cells have escaped from the vessel and are seen among the cells of the adjacent tissues.

a. capillary vessel (Fig. 6 "*i*").
b. red blood-cells.
c. nucleus of an endothelial cell.
d. red blood-cell outside the capillary vessel.
e. the last endothelial cell of the capillary wall.
f. a large cell with rosette-like nuclear figure.
g. remnant of partition between capillary vessel and intervillous space.
h. intervillous space.
i. gap in capillary wall, allowing escape of blood-cells.

Fig. 8. From Section 274 (magnification &c. as in Fig. 7). This gives another illustration of the fate of the capillary endothelium where invaded by embryonic tissues. The capillary wall simply breaks down and the blood then bathes the embryonic cells. Red blood-cells have also escaped into the maternal tissues. In the blood stream are seen two examples of leucocytes with nuclei arranged in "tetrads" (cf. text).

a. capillary vessel.
b. red blood-cells.
c. nuclei of endothelial cells.
c'. nuclei beyond which no endothelium is recognisable on embryonic side.
d. red blood-cells in intercellular spaces.
e. a leucocyte with curious nucleus ("tetrad").
e'. a leucocyte in an intervillous space.
f. indefinite material, probably remains of syncytial tissue.
g. commencement of an intervillous space.

Figs. 9, 10, 11. Sections 263, 265, 267 (magnification &c. as in Fig. 7). The appearances here seen bear the interpretation that a mass of embryonic cells of syncytial type approaches (Figs. 9, 10) and invades (Fig. 11) the cavity of an uterine gland into which haemorrhage has previously taken place.

Fig. 9. *a.* lumen of uterine gland.
b. degenerating gland-epithelium.
c. mass of tissue regarded as embryonic (syncytial).
d. cells between embryonic tissue and lumen of gland.
e. red blood-cell.

Fig. 10. *a.* lumen of uterine gland.
b. degenerating gland-epithelium.
c. mass of tissue regarded as embryonic (syncytial).
d. mass of red blood-cells in lumen of gland.
e. red blood-cell.

Fig. 11. *a.* lumen of uterine gland.
b. degenerating gland-epithelium.
c. mass of tissue regarded as embryonic (syncytial).
d. mass of red blood-cells in lumen of gland.
e. red blood-cell.
f. leucocyte with curious nucleus ("tetrad").

Fig. 12. Transverse section of an embryonic villus from Section 115 (magnification &c. as in Fig. 7). The villus projects into an intervillous space. Centrally the cells are provided with cell-walls and peripherally is a protoplasmic covering with rare nuclei. The peripheral tissue is stained more deeply than the central cells, and is regarded as representing the syncytial layer (Voigt's Deckschicht) while the central cells correspond to those of Langhans' layer (Voigt's Grundschicht).

a. inner cell of villus.
b outer covering of villus with nuclei.
c. red blood-cell in intervillous space.

Fig. 1.

Fig. 2.

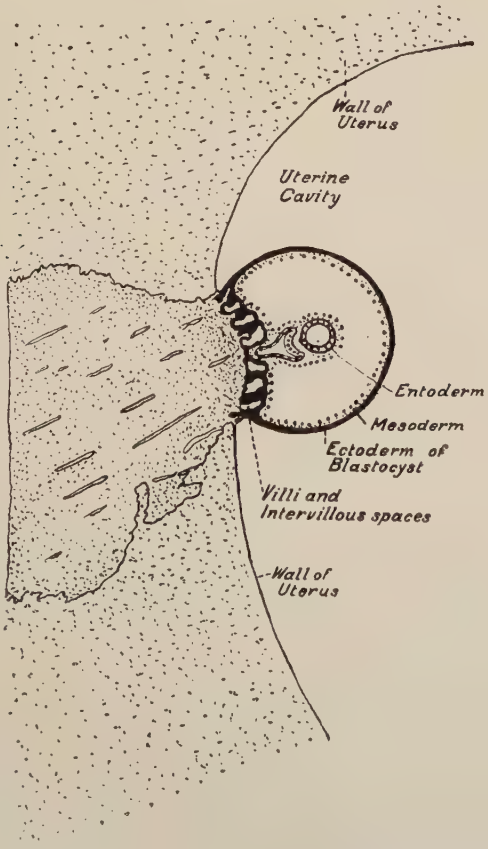


Fig. 3.

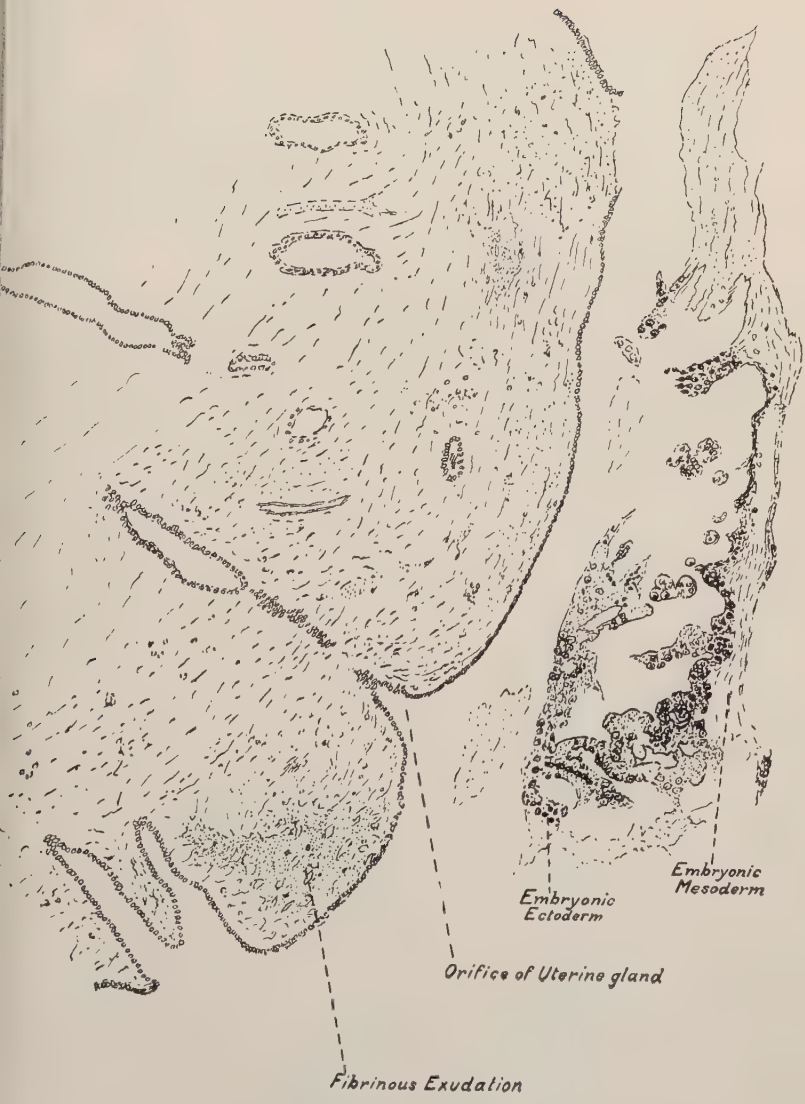

Embryonic Mesoderm
Embryonic Ectoderm
Orifice of Uterine gland
Fibrinous Exudation

Fig. 4.

Fig 5.

Fig. 6.

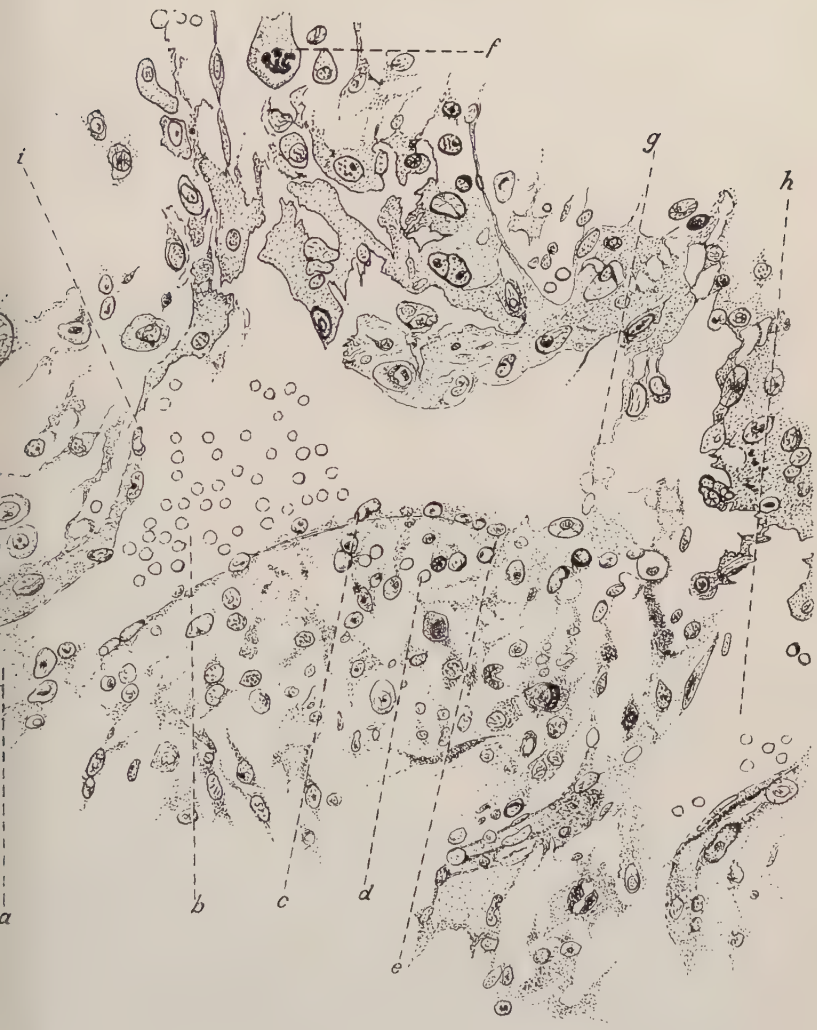


Fig. 7.

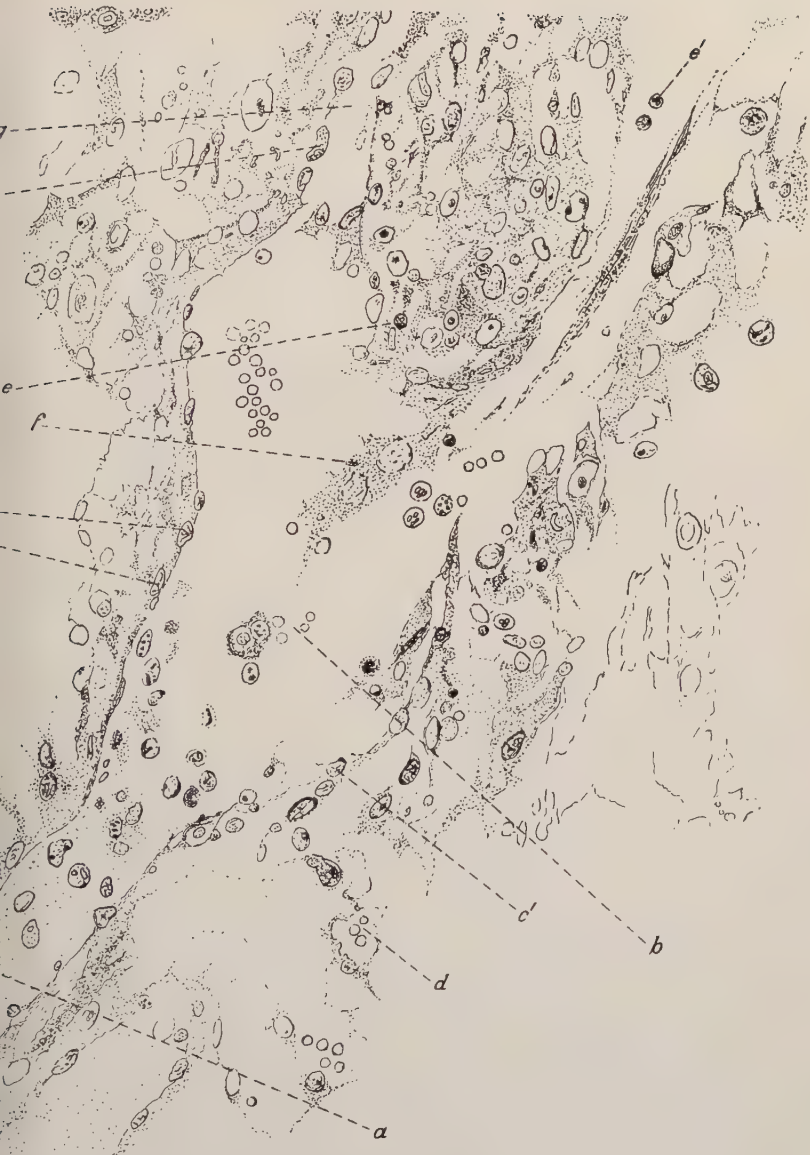


Fig. 8.

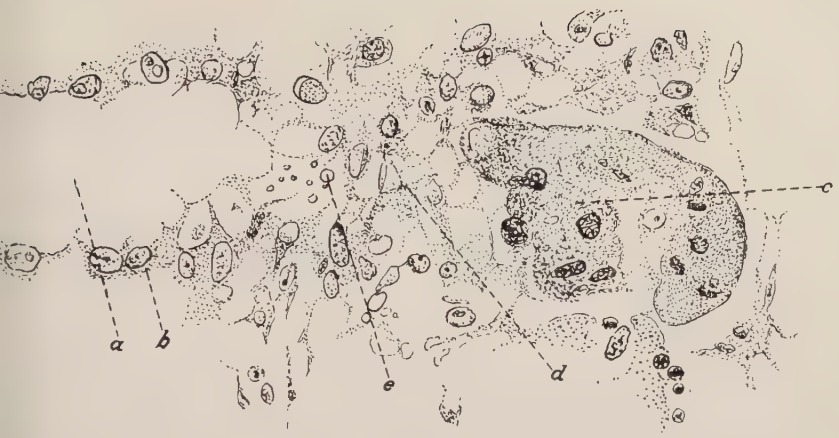


Fig. 9.

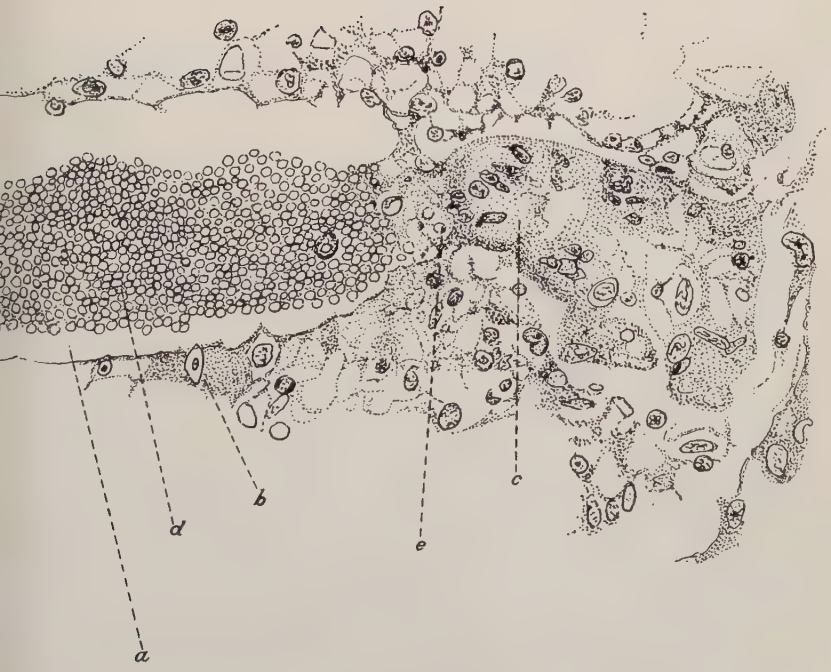


Fig. 10.

Fig. 11.

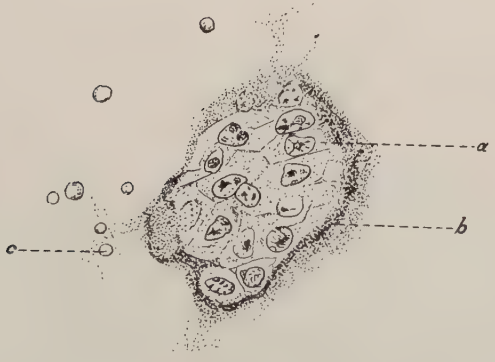


Fig. 12.

On the theory of the rotation of the plane of polarization by solutions. By Prof. J. J. Thomson, M.A., F.R.S.

[*Read* 20 May 1907.]

The rotation of the plane of polarization by solutions of such substances as sugar or tartaric acid has been the subject of many investigations largely owing to the fact that by the theory of the unsymmetric carbon atom developed by Van 't Hoff and Le Bel, the measurement of the rotation of the plane of polarization by a substance affords a valuable means of determining the chemical structure of the atom of the substance. Very little work seems, however, to have been done in connection with the theory of this effect. In this paper I propose to discuss under what conditions a collection of atoms would possess the power of rotation if each atom consisted of a number of electrified parts rigidly connected together.

First, let us consider what terms in the mathematical equations which express the propagation of waves of light represent this effect. If X, Y, Z are the components of the electric force, α, β, γ those of the magnetic force, u, v, w the components of the current, then,

$$\frac{dZ}{dy} - \frac{dY}{dz} = -\mu \frac{d\alpha}{dt},$$

$$\frac{dX}{dz} - \frac{dZ}{dx} = -\mu \frac{d\beta}{dt},$$

$$\frac{dY}{dx} - \frac{dX}{dy} = -\mu \frac{d\gamma}{dt};$$

$$\frac{d\gamma}{dy} - \frac{d\beta}{dz} = 4\pi u,$$

$$\frac{d\alpha}{dz} - \frac{d\gamma}{dx} = 4\pi v,$$

$$\frac{d\beta}{dx} - \frac{d\alpha}{dy} = 4\pi w,$$

where μ is the magnetic permeability of the medium.

If no matter is present, the current is merely the polarization current whose components are $\frac{K}{4\pi}\frac{dX}{dt}$, $\frac{K}{4\pi}\frac{dY}{dt}$, $\frac{K}{4\pi}\frac{dZ}{dt}$, where K is the specific inductive capacity of the medium. When, how-

ever, matter is present whose molecules are made up of charged parts, then the motion of these parts under the electric field in the light wave may give rise to convection currents which have to be included in u, v, w, and which will modify the equations.

From equations (2) and (1), we have

$$\frac{d}{dy}\left(\frac{dY}{dx}-\frac{dX}{dy}\right)-\frac{d}{dz}\left(\frac{dX}{dz}-\frac{dZ}{dx}\right)=-4\pi\mu\frac{du}{dt},$$

or since

$$\frac{dX}{dx}+\frac{dY}{dy}+\frac{dZ}{dz}=0,$$

$$\frac{d^2X}{dx^2}+\frac{d^2X}{dy^2}+\frac{d^2X}{dz^2}=4\pi\mu\frac{du}{dt}\qquad\ldots\ldots\ldots\ldots\ldots\ldots(3),$$

with similar equations for Y and Z.

If the nature of the body through which the light passes is such that $\frac{du}{dt}$ contains a term $r\left(\frac{dY}{dz}-\frac{dZ}{dy}\right)$, the equation (3) will take the form

$$\frac{d^2X}{dx^2}+\frac{d^2X}{dy^2}+\frac{d^2X}{dz^2}=\mu K\frac{d^2X}{dt^2}+4\pi\mu r\left(\frac{dY}{dz}-\frac{dZ}{dy}\right),$$

with equations of a similar type for Y and Z, we can easily show that equations of this type represent a rotation of the plane of polarization equal to $2\pi r\mu$ per unit path.

Let us now calculate the expression convection current produced by the light waves acting on the atoms of the substance.

Let us suppose that each atom consists of a number of electrified bodies rigidly connected together. To find how these move when the light wave falls upon them, take as the origin the centre of gravity of an atom and for axes x', y', z' fixed in the atom, such that if $e_1, e_2, \ldots$ are the charges on the parts of the atom whose co-ordinates are respectively (x_1', y_1', z_1'), (x_2', y_2', z_2'), …, then

$$\Sigma(e_1x_1'y_1')=\Sigma(e_1x_1'z_1')=\Sigma(e_1y_1'z_1')=0.$$

Let ω_1, ω_2, ω_3 be the angular velocity of the atom round the axes of x', y', z' respectively, D, E, F, L, M, N the moments and products of inertia of the atom about these axes, then, neglecting powers of the ω's higher than the first, we have

$$\frac{d}{dt}(-D\omega_1-N\omega_2-M\omega_3)=P,$$

$$\frac{d}{dt}(-N\omega_1-E\omega_2-L\omega_3)=Q,$$

$$\frac{d}{dt}(-M\omega_1-L\omega_2-F\omega_3)=R,$$

where P, Q, R are the moments of the forces around the axes of x', y', z' respectively, solving these equations, we get

$$\left.\begin{aligned}\frac{d\omega_1}{dt} &= pP + \nu Q + \mu R,\\ \frac{d\omega_2}{dt} &= \nu P + qQ + \lambda R,\\ \frac{d\omega_3}{dt} &= \mu P + \lambda Q + rR,\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4),$$

where p, q, r, λ, μ, ν are quantities depending on the masses and positions of the electrified bodies, but not upon their electrical charges.

If X_1', Y_1', Z_1' are the components of the electric force at the points x_1', y_1', z_1', where the charge of electricity is e_1, then

$$P = \Sigma\,(Z_1'y_1' - Y_1'z_1')\,e_1.$$

If (l_1, m_1, n_1), (l_2, m_2, n_2), (l_3, m_3, n_3) are the direction-cosines of the axes x', y', z' with reference to fixed axes x, y, z and X_1, Y_1, Z_1, the components of (X_1', Y_1', Z_1') along x, y, z, then

$$\begin{aligned}X_1' &= l_1X_1 + m_1Y_1 + n_1Z_1,\\ Y_1' &= l_2X_1 + m_2Y_1 + n_2Z_1,\\ Z_1' &= l_3X_1 + m_3Y_1 + n_3Z_1.\end{aligned}$$

If X_0, Y_0, Z_0 are the values of X, Y, Z at the origin of the x', y', z' axes, then, retaining only the first powers of x', y', z',

$$X_1 = X_0 + (l_1x_1' + l_2y_1' + l_3z_1')\frac{dX_0}{dx} + (m_1x_1' + m_2y_1' + m_3z_1')\frac{dX_0}{dy} + (n_1x_1' + n_2y_1' + n_3z_1')\frac{dX_0}{dz},$$

$$Y_1 = Y_0 + (l_1x_1' + l_2y_1' + l_3z_1')\frac{dY_0}{dx} + (m_1x_1' + m_2y_1' + m_3z_1')\frac{dY_0}{dy} + (n_1x_1' + n_2y_1' + n_3z_1')\frac{dY_0}{dz},$$

$$Z_1 = Z_0 + (l_1x_1' + l_2y_1' + l_3z_1')\frac{dZ_0}{dx} + (m_1x_1' + m_2y_1' + m_3z_1')\frac{dZ_0}{dy} + (n_1x_1' + n_2y_1' + n_3z_1')\frac{dZ_0}{dz}.$$

Substituting these values of Z', Y' in P and remembering that $\Sigma e_1x_1'y_1' = \Sigma e_1x_1'z_1' = \Sigma e_1y_1'z_1' = 0$, we see that as far as terms in $\frac{dY}{dz}$ and $\frac{dZ}{dy}$ are concerned,

$$\left.\begin{aligned} P &= (Bm_2n_3 - Cm_3n_2)\frac{dZ}{dy} - (Cn_3m_2 - Bn_2m_3)\frac{dY}{dz}, \\ Q &= (Cm_1n_3 - Am_3n_1)\frac{dZ}{dy} - (Am_1n_3 - Cn_1m_3)\frac{dY}{dz}, \\ R &= (Am_1n_2 - Bn_1m_2)\frac{dZ}{dy} - (Bn_2m_1 - Am_1m_2)\frac{dY}{dz}, \end{aligned}\right\} \quad \ldots\ldots(5),$$

where $A = \Sigma e_1 x_1'^2$, $B = \Sigma e_1 y_1'^2$, $C = \Sigma e z'^2$ and may be called the electrical moments of inertia.

The convection current parallel to x is equal to

$$\Sigma e_1 \frac{dx}{dt} = \Sigma e_1 \frac{d}{dt}(l_1 x' + l_2 y' + l_3 z').$$

Now, since l_1, l_2, l_3 are the direction-cosines of a line fixed in space with reference to the axes x', y', z',

$$\frac{dl_1}{dt} = \omega_2 l_3 - \omega_3 l_2,$$

$$\frac{dl_2}{dt} = \omega_3 l_1 - \omega_1 l_3,$$

$$\frac{dl_3}{dt} = \omega_1 l_2 - \omega_2 l_1.$$

Hence u, the x component of the convection current, is equal to

$$\Sigma \{e_1 x_1' (\omega_2 l_3 - \omega_3 l_2) + e_1 y_1' (\omega_3 l_1 - \omega_1 l_3) + e_1 z' (\omega_1 l_2 - \omega_2 l_1)\},$$

and neglecting the squares of ω_1, ω_2, ω_3, we have

$$\frac{du}{dt} = \Sigma \left\{ e_1 x_1' \left(l_3 \frac{d\omega_2}{dt} - l_2 \frac{d\omega_3}{dt} \right) + e_1 y_1' \left(l_1 \frac{d\omega_3}{dt} - l_3 \frac{d\omega_1}{dt} \right) + e_1 z_1' \left(l_2 \frac{d\omega_1}{dt} - l_1 \frac{d\omega_2}{dt} \right) \right\},$$

substituting for $\frac{d\omega_1}{dt}$, $\frac{d\omega_2}{dt}$, $\frac{d\omega_3}{dt}$ from equations (1)

$$\begin{aligned} \frac{du}{dt} = {} & (pP + \nu Q + \mu R)(l_2 \Sigma e_1 z_1 - l_3 \Sigma e_1 y_1) \\ & + (\nu P + qQ + \lambda R)(l_3 \Sigma e_1 x_1 - l_1 \Sigma e_1 z_1) \\ & + (\mu P + \lambda Q + rR)(l_1 \Sigma e_1 y_1 - l_2 \Sigma e_1 x_1). \end{aligned}$$

Now

$$l_1 = m_3 n_2 - m_2 n_3, \quad l_2 = m_1 n_3 - m_3 n_1, \quad l_3 = m_2 n_1 - m_1 n_2.$$

Substituting for P, Q, R the values just found and averaging for all the molecules in unit volume, the axes of these molecules being supposed uniformly distributed, we get

$$\frac{du}{dt} = N\beta\left[\nu\{C+A-(B+C)\}\Sigma ez' + \mu\{B+C-(B+A)\}\Sigma ey'\right.$$
$$\left. + \lambda\{A+B-(A+C)\}\Sigma ex'\right]\left(\frac{dZ}{dy}-\frac{dY}{dz}\right)$$
$$= N\beta\{\lambda\Sigma ex'(B-C)+\mu\Sigma ey'(C-A)$$
$$+\nu\Sigma ez'(A-B)\}\left(\frac{dZ}{dy}-\frac{dY}{dz}\right),$$

where N is the number of systems per unit volume and β the mean value of $m_1^2 n_3^2$ or $m_3^2 n_1^2$ for a uniform distribution of axes.

Thus, if the coefficient of $\frac{dZ}{dy}-\frac{dY}{dz}$ in the preceding expression does not vanish, a substance formed of such atoms as we have been considering will rotate the plane of polarization. Unless the atom possesses a considerable amount of want of symmetry the coefficient will vanish. Thus, if the axes of x', y', z' which, by definition, are principal axes for the electrical charges are also principal axes for the masses λ, μ, ν will all vanish and there will be no rotation. Again, if the 'electrical centre' of the negative charges coincides with that of the positive charges,

$$\Sigma ex' = \Sigma ey' = \Sigma ez' = 0,$$

and again there is no rotation, and if $A = B = C$, *i.e.* if the principal 'electrical moments of inertia' are equal, the coefficient again vanishes.

If the charges were in one plane, then taking this as the plane of z' we have $\Sigma ez' = 0$, and since L and M vanish we see that $\lambda = \mu = 0$, hence the coefficient vanishes and there is no rotation.

PROCEEDINGS AT THE MEETINGS HELD DURING THE SESSION 1906—1907.

ANNUAL GENERAL MEETING.

October 29th, 1906.

In the Optical Lecture Room.

Dr Fenton, Vice-President, in the Chair.

The following were elected officers for the ensuing year:

President:

Dr Hobson.

Vice-Presidents:

Dr Baker.
Dr Fenton.
Mr D. Sharp.

Treasurer:

Mr H. F. Newall.

Secretaries:

Mr A. E. Shipley.
Dr E. W. Barnes.
Mr P. V. Bevan.

Other Members of the Council:

Professor Nuttall.
Mr S. Ruhemann.
Dr Anderson.
Mr A. Hutchinson.
Mr F. F. Blackman.
Mr H. W. Richmond.
Mr F. G. Hopkins.
Mr A. Harker.
Professor Larmor.
Professor Thomson.
Dr Duckworth.
Mr W. G. Fearnsides.

The following was elected a Fellow of the Society:

Rev. A. V. Valentine-Richards, Christ's College.

The following were elected Associates of the Society:

G. A. Carse, Emmanuel College.
D. Comstock.

The following Communications were made:

1. On the procession of *Cnethocampa pinivorax*. By H. H. Brindley, M.A., St John's College.

2. A note on a Collection of Oribatidae from British Guiana. By C. Warburton, M.A., Christ's College, and N. D. F. Pearce, M.A., Trinity College.

3. The influence of spectral colours on the sporulation of various species of Saccharomyces. By J. E. Purvis, M.A., St John's College, and G. R. Warwick, B.A., Pembroke College.

November 12*th*, 1906.

In the Optical Lecture Room.

Dr Hobson, President, in the Chair.

The following was elected an Associate of the Society:

L. T. More.

The following Communications were made:

1. On Electrification produced by heating salts. By Professor Thomson.

2. On Secondary Röntgen rays. By Professor Thomson.

3. On the specific heat of gases at constant volume and high pressure. By W. A. D. Rudge, M.A., St John's College.

4. The Radioactivity of the Alkali metals. By N. R. Campbell, M.A., Trinity College, and A. Wood, Emmanuel College.

5. A relation between the ionic velocity and the volume of organic ions in aqueous solutions. By G. A. Carse, and T. H. Laby. (Communicated by Professor Thomson.)

November 26th, 1906.

In the Chemical Laboratory.

DR FENTON, VICE-PRESIDENT, IN THE CHAIR.

The following were elected Fellows of the Society:

E. A. N. Arber, M.A., Trinity College.
F. J. Dykes, B.A., Trinity College.
F. Horton, B.A., St John's College.
F. E. E. Lamplough, B.A., Trinity College.
J. W. Nicholson, B.A., Trinity College.
N. D. F. Pearce, M.A., Trinity College.
F. A. Potts, B.A., Trinity Hall.
R. H. Rastall, M.A., Christ's College.
F. R. C. Reed, M.A., Trinity College.
W. Spens, B.A., King's College.
H. Woods, M.A., St John's College.

The following Communications were made:

1. A delicate reaction for Carbohydrates. By H. J. H. FENTON, Sc.D., Christ's College.

2. Xanthoxalanil and its Analogues. By S. RUHEMANN, M.A., Gonville and Caius College.

3. The influence of a strong magnetic field on the spark spectra of titanium, chromium, and manganese. By J. E. PURVIS, M.A., St John's College.

4. The Solubility of Stereoisomerides in Optically Active Solvents. By H. O. JONES, M.A., Clare College.

5. Estimation of Copper. By W. H. FOSTER, B.A., St John's College. (Communicated by Mr H. O. Jones.)

6. On the Maturation of the Germ-cells in the Sawfly (*Nematus ribesii*). (Third note.) By L. DONCASTER, M.A., King's College.

January 28th, 1907.

In the Optical Lecture Room.

DR HOBSON, PRESIDENT, IN THE CHAIR.

The following were elected Fellows of the Society:

W. E. Dixon, M.A., Downing College.
W. Ridgeway, M.A., Gonville and Caius College. Disney Professor of Archaeology.
G. E. Wherry, M.A., Downing College.

The following Communications were made:

1. Kanalstrahlen in Helium. By J. J. Thomson, M.A., Cavendish Professor of Experimental Physics.

2. An experiment with a pair of Robison ball-ended magnets. By G. F. C. Searle, M.A., Peterhouse.

3. A method of determining the thermal conductivity of India-rubber. By G. F. C. Searle, M.A., Peterhouse.

4. A curvature method for measuring surface tension. By C. T. R. Wilson, M.A., Sidney Sussex College.

5. The application of integral equations to the determination of expansions in series of oscillating functions. By H. Bateman, M.A., Trinity College.

February 11*th*, 1907.

In the Botany School.

Mr D. Sharp, Vice-President, in the Chair.

The following were elected Fellows of the Society:

F. W. Dootson, M.A., Trinity Hall.
J. W. Landon, M.A., Sidney Sussex College.
A. Wood, B.A., Emmanuel College.

The following Communications were made:

1. On the mode of formation of the initial cell-wall. By W. Gardiner, Sc.D., Clare College.

2. The Races of Modern Egypt. By C. S. Myers, M.D., Gonville and Caius College.

3. Notes on the structure and behaviour of the larva of *Anopheles maculipennis*. By A. D. Imms, Christ's College. (Communicated by Mr A. E. Shipley.)

February 25*th*, 1907.

In the Anatomy School.

Dr Hobson, President, in the Chair.

The following were elected Fellows of the Society:

S. W. Cole, M.A., Trinity College.
J. H. Widdicombe, M.A., Downing College.

The following was elected an Associate of the Society:

C. V. Burton.

The following Communications were made:

1. Some points in the anatomy of the peripheral nerves. By E. Barclay-Smith, M.D., Downing College.

2. On an occipital vermian fossa and cerebellar vermian eminence. By G. F. Rogers, M.D., Gonville and Caius College. (Communicated by Professor Macalister.)

3. The tendency to fusion shown by the sub-occipital vertebrae. By A. Macalister, M.D., Professor of Anatomy.

4. The range of variation in the navicular bone. By T. Manners-Smith, M.B., Downing College. (Communicated by Professor Macalister.)

5. The histology of the early placenta in Semnopithecus. By W. L. H. Duckworth, M.D., Sc.D., Jesus College.

6. A chemical test for "strength" in wheat-flour. By T. B. Wood, M.A., Gonville and Caius College.

March 11*th*, 1907.

In the Chemical Laboratory.

Dr Hobson, President, in the Chair.

The following were elected Fellows of the Society:

W. Burton, B.A., Emmanuel College.
G. F. Rogers, M.D., Gonville and Caius College.
A. G. Tansley, M.A., Trinity College.

The following Communications were made:

1. Reduction of Carbon dioxide to Formaldehyde. (Preliminary note.) By H. J. H. Fenton, Sc.D., Christ's College.

2. Dithioxanthoxalanil and its Homologues. By S. Ruhemann, M.A., Gonville and Caius College.

3. Some observations on complex carbonates. By T. B. Wood, M.A., Gonville and Caius College, and H. O. Jones, M.A., Clare College.

4. An optically active Tetrahydroquinoline compound. By F. Buckney, B.A., Sidney Sussex College. (Communicated by Mr H. O. Jones.)

5. A series of substituted Bromanilines. By J. R. Hill, B.A., St John's College. (Communicated by Mr H. O. Jones.)

6. Some new Platinocyanides. By L. A. Levy, Clare College. (Communicated by Dr Fenton.)

7. The resolution of salts of asymmetric nitrogen compounds and weak acids. By Miss A. Homer, Newnham College. (Communicated by Mr H. O. Jones.)

8. A new coloured fluorescent hydrocarbon. By Miss A. Homer, Newnham College. (Communicated by Mr H. O. Jones.)

9. Notes on the proportion of the sexes in dogs. By W. Heape, M.A., Trinity College.

10. Preliminary note upon the presence of Phosphorus in Crystalline Egg albumin. By Miss E. G. Willcock, Newnham College, and W. B. Hardy, M.A., Gonville and Caius College.

11. The variation of the absorption bands of a crystal in a magnetic field. By W. M. Page, B.A., King's College. (Communicated by Mr H. W. Richmond.)

12. The natural units of Mass, Length, and Time. By H. C. Pocklington, M.A., St John's College.

May 6th, 1907.

In the Optical Lecture Room.

Dr Hobson, President, in the Chair.

The following was elected a Fellow of the Society:

W. A. H. Harding, B.A., Peterhouse.

The following Communications were made:

1. The spark-spectra of lead, tin, antimony, bismuth and gold, in a strong magnetic field. By J. E. Purvis, M.A., St John's College.

2. β-rays from Potassium. By N. R. Campbell, M.A., Trinity College.

3. The number of Electrons in an Atom. By N. R. Campbell, M.A., Trinity College.

4. On the Longitudinal Impact of metal rods with rounded ends. By J. E. Sears, B.A., St John's College. (Communicated by Professor Hopkinson.)

5. Selective absorption of Röntgen Rays. By G. W. C. Kaye, Trinity College. (Communicated by Professor Thomson.)

6. On the transmission of Earthquakes through the earth. (Second paper.) By Rev. O. Fisher, Jesus College.

7. Note on the influence of extraneous forces upon the proportion of the sexes produced by Canaries. By W. Heape, M.A., Trinity College.

May 20th, 1907.

In the Botany School.

Dr Hobson, President, in the Chair.

The following were elected Fellows of the Society:

F. T. Brooks, B.A., Gonville and Caius College.
T. Manners-Smith, M.B., Downing College.
W. M. Page, B.A., King's College.

The following Communications were made:

1. Exhibition of photomicrographs of wood-sections made by Mr J. A. Weale. By E. R. Burdon, M.A., Sidney Sussex College.

2. Parasitic trees of southern India. By C. A. Barber, Sidney Sussex College. (Communicated by Professor Seward.)

3. Physiology of Plants in the Tropics:

(α) Internal temperature of insolated leaves.
(β) Periodicity of growth in Ceylon.
(γ) Respiration of water Plants.

By A. M. Smith, B.A., Emmanuel College. (Communicated by Mr F. F. Blackman.)

4. Notes on the parasitism of Botrytis. By F. T. Brooks, B.A., Gonville and Caius College. (Communicated by Mr F. F. Blackman.)

5. A representation of the exponential function as an infinite product. By G. B. Mathews, M.A., St John's College.

6. Some theorems on Integral Equations. By H. Bateman, M.A., Trinity College.

7. On the theory of the rotation of the plane of polarization by solutions. By J. J. Thomson, M.A., Cavendish Professor of Experimental Physics.

PROCEEDINGS

OF THE

Cambridge Philosophical Society.

A critical description of three cases of Single Hypogastric artery in the Human Foetus. By W. L. H. Duckworth, M.A., M.D., Sc.D., Jesus College. [Plates XII. and XIII.]

[*Read* 11 November 1907.]

The teratological specimens which have provided material for the following observations are human monstrosities in the Anthropological Laboratory at the Anatomy School. In each instance the hinder end of the trunk and the lower limbs are affected and malformed. The disturbance is greatest in the specimen designated F, which is a symelian or sirenian monster. Of the two remaining specimens, A and E, the latter (E) approaches the sirenian type, while in A the principal local defect noticed on superficial inspection is club-foot or talipes varus. All three specimens agree in the possession of a single artery (accompanying the umbilical vein) instead of the two arteries normally present. The present account consists of an investigation of the conditions associated with this anomaly, and some comments upon the results of the investigation are appended. The three specimens will be considered in alphabetical order.

I. Specimen A. The general anatomy of this monster has been described in Schwalbe's *Zeitschrift für Morphologie und Anthropologie* (Band x, Heft 3, 1907), so that it is unnecessary to enter into much detail in the present connexion. The sex is male, and when first received the specimen measured 290 mm. from vertex to coccyx, and weighed 2073 gm. It is therefore to be regarded as a foetus of the ninth month.

The single umbilical artery in A (Figs. 1 and 2) appears to be the main continuation of the left common iliac vessel. It is particularly remarkable that the internal iliac artery on this

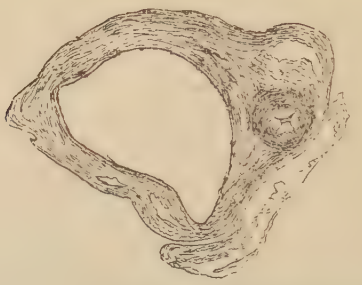


Fig. 1. Transverse section (×8) through the umbilical cord of specimen A. The single umbilical artery is seen on the right side of the drawing.

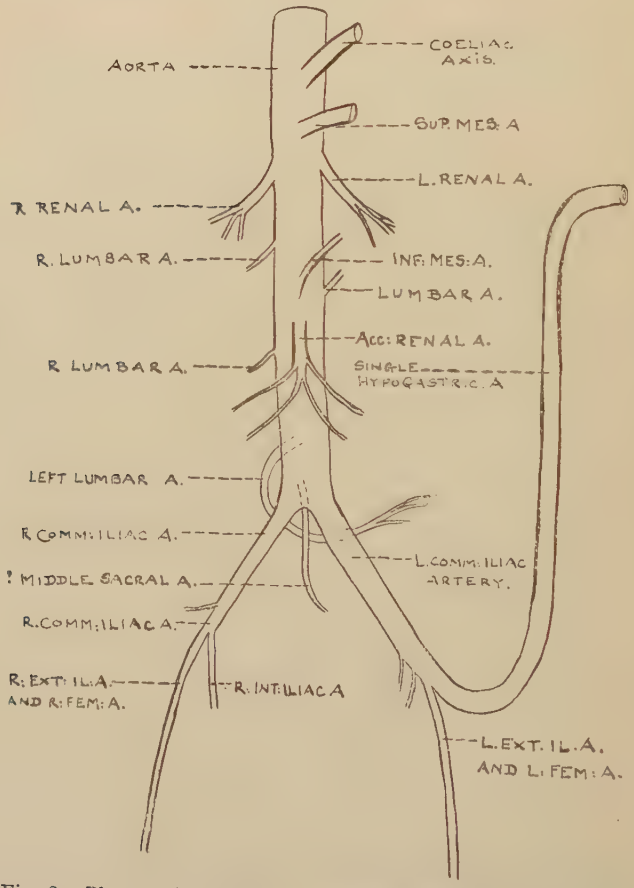


Fig. 2. Plan of the principal abdominal arteries of specimen A.

side is represented by two small branches of the common iliac artery so that the umbilical artery does not arise from the internal iliac vessel as is normally the case. On the right side there is no hypogastric nor umbilical artery, and it therefore appears that the vessel on this side of the body has failed to appear or else has been suppressed.

It should be noticed that the superior mesenteric artery in specimen A is distinct. There was a large exomphalic tumour containing various intestinal loops, including the caecum and appendix.

II. Specimen E is a good deal smaller than specimen A, and its age is estimated as about six months. From vertex to coccyx the length is 200 mm., and the specimen after several years immersion in alcohol, weighed 801 gm. The dimensions of the head are: maximum length 102 mm.: maximum breadth 71 mm.: maximum "horizontal" circumference 280 mm. Neither head nor cerebrum is malformed, and herein lies a contrast with specimen A. No external genitalia are present. From the external conformation the diagnosis of sex is therefore impossible, but the intra-abdominal sex-gland shews ovarian characters (though these are modified), and the sex is thus shewn to be female.

Both right and left upper limbs and the left lower limb are much deformed, and their general appearance is shewn in the accompanying photograph (Plate xii, Fig. 3). The lower limbs have been abnormally rotated, torsion having occurred in the same sense as in the upper limbs. This is most marked in the footless left limb, and in both, the flexor muscles of the knee are on the anterior and not the posterior aspect of the thigh while the leg bends forwards at the knee, and thus resembles the forearm at the elbow. The right leg is abnormal only in respect of this unusual rotation, the degree or extent of which is less than in the left leg, and in making the photograph represented in Fig. 3, this limb was drawn as nearly as possible into the normal position. Thus is explained the apparent discrepancy between the appearances seen in Fig. 3, and the account in the text. Other skeletal peculiarities are revealed by the skiagram reproduced in Plate xii, Fig. 4.

The anterior abdominal wall is not abnormal and no hernial protrusion exists. The umbilical vein is traceable as the ductus venosus to the inferior vena cava. The thymus body is unusually small and the heart has a bifid ventricular apex. The spleen is accompanied by two small accessory bodies. Remnants of the suprarenal bodies can be identified, but no kidneys can be found.

Sex-glands (female) are present but there is no bladder.

The intestine was interrupted at several points and ends blindly, the anus being imperforate.

Such conditions of the lower limb and of the genitalia and intestine are strongly reminiscent of the sireniform type of monster, of which variety specimen E is evidently an "incomplete" or aberrant example.

The mode of origin of the single umbilical artery (Fig. 5) is shewn in the accompanying plan (Fig. 6) of the branches of the

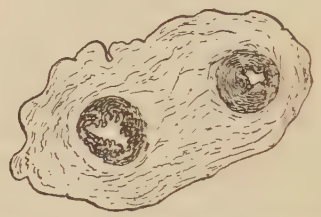


Fig. 5. Transverse section (×8) through the umbilical cord of specimen E. The single umbilical artery is seen on the right side of the drawing.

abdominal aorta. The latter, after giving off the coeliac axis, the superior mesenteric and the uppermost lumbar arteries, divides unequally, and the larger branch forming the main continuation of the parent aorta becomes the single umbilical artery of the cord. The point of bifurcation is too near the diaphragm to be regarded as the normal iliac division. Moreover, the smaller branch at the bifurcation continuing down the vertebral column, gives off smaller branches both right and left, so that it is clearly a much-diminished dorsal aorta. Nevertheless, on arriving at the pelvic brim this median dorsal aorta bears to the right, and the next twigs given off correspond to the internal iliac tributaries of the (single) inferior vena cava. Next, this artery passes into the thigh, and evidently becomes the common femoral with superficial and deep branches. The superficial division passing down Hunter's canal is easily exposed in the popliteal space (owing to the outward rotation of the thigh) and becomes the popliteal artery as in normal examples. In this smaller branch we recognise thus a reduced dorsal aorta passing successively into right common iliac, right external iliac, right common femoral and other normal limb branches. The internal iliac artery is much diminished in size and importance, and no hypogastric branch could be seen.

Returning to the larger branch into which the abdominal aorta divides, it is to be noted that though it passes almost unchanged in calibre to the umbilical cord, yet it provides an artery for the left sex-gland, and gives off a slender branch which at the pelvic margin becomes the left common femoral with such subsidiary branches as can be recognised in the peg-top-shaped left lower limb.

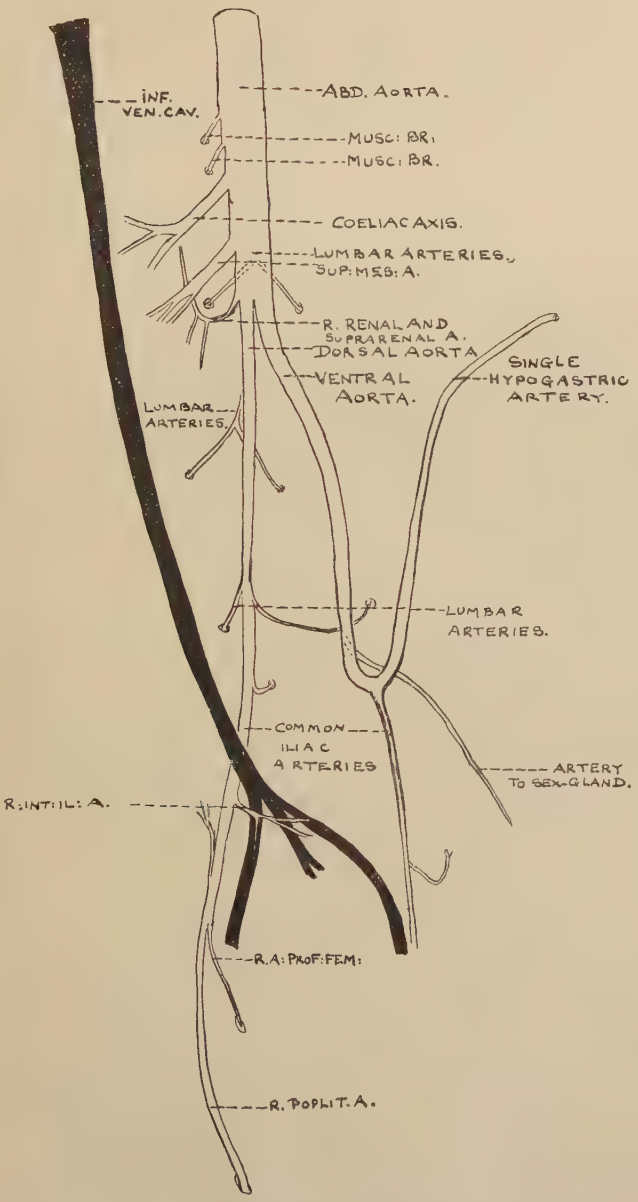


Fig. 6. Plan of the principal abdominal arteries of specimen E.

The phenomenon of a single umbilical artery, arising as this one does from the more anterior portion of the abdominal aorta is evidently quite distinct from that observed in specimen A, as is shewn by a comparison of Fig. 6 with Fig. 1.

The interpretation of the anomaly in specimen E is rendered clearer by the study of specimen F, to which attention is now directed.

III. In bulk, specimen F (Plate xiii, Figs. 7, 8, 9) corresponds to the normal average human foetus at the ninth month. The sex is female. From vertex to coccyx the length is 280 mm., and from vertex to heel 447 mm. After some weeks' immersion in a mixture of alcohol and formalin, the specimen weighed 2800 gm. The dimensions of the head are as follows: length 113 mm.: breadth 90 mm.: circumference 332 mm.

The head, neck, upper limbs and the upper part of the torso generally, are not deformed. A very distinct musculus sternalis is present on the right side.

The lower limbs are conjoined from the hips to the ankles: the soles of the feet are inverted, and the feet diverge anteriorly. A skiagram shews that the skeleton of each lower limb has been formed even where the softer overlying tissues are joined.

From the abdomen an umbilical hernia protrudes. The contents of the sac are as follows:

(*a*) about 4 in. of the small intestine with a distinct and free Meckel's diverticulum;

(*b*) part of the quadrate lobe of the liver, which is very curiously prolonged to reach this position;

(*c*) the umbilical vein, a single umbilical artery and the urachus (Fig. 10) in which a lumen (still lined with epithelium) is conspicuous in transverse sections.

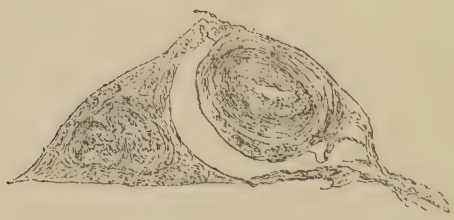


Fig. 10. Transverse section (×8) of the urachus (on the left) and the single umbilical artery (to the right of the drawing) in specimen F.

From the lower aspect of the hernia the umbilical cord (Fig. 11) arises and is found to contain the structures enumerated in (*c*) above.

There is no record of the condition or conformation of the placenta. The body is fat and well-nourished, the abdomen being rather protuberant. At the pubes, no external genitalia have been formed, and though a small median papilla is attached to the suprapubic region, it proved, on histological examination, to consist only of epidermal and dermal tissues, while lacking any distinctive mammary structure.

Fig. 11. Transverse section (×8) through the umbilical cord of specimen F. The single umbilical artery is seen to the right of the drawing.

Posteriorly, in the coccygeal region, a small dimple with a coccygeal vortex of fine hairs was seen. Below this a sessile penis-like organ projects. This is evidently an enlarged clitoris. The cleft-like depression to its right side is a cul-de-sac, so that the anus is imperforate.

The abdomen was opened and a dissection was made with a view of tracing the different branches of the abdominal aorta. Incidentally the following conditions were observed. The umbilical vein resembles that of specimen E (and of the normal foetus) in its continuity with the ductus venosus and inferior caval vein.

The great omentum is absent. There is a partial duodenal mesentery, but the mesenteric attachment to the posterior abdominal wall is greatly circumscribed, being concentrated near the duodenum and not extended to the right iliac region. The liver is very large, the excess being due to the extensive and massive left lobe which is also subdivided. The quadrate lobe is so far prolonged downwards that it enters the cavity of the umbilical hernia. The left lobe sends forwards a deeply notched offshoot which hangs down in front of the intestines.

The pelvic viscera are in an abnormal state of development,

the cloaca being but partially subdivided, and although recognisable by their position, the portions referable to bladder, uterus, and rectum are conjoined. From the lower surface of the imperforate cloaca, an urethral process passes directly backwards to end eventually as the sessile clitoris already seen in the gluteal region.

The sex is clearly shewn by the pelvic organs, for an ovary is present on each side, together with the corresponding Fallopian tube. Suprarenal bodies are present, and very large. The right kidney is represented by a large multilocular cyst, which touches the left kidney. The latter is unusually small, tough, and elastic. From each kidney, the ureter passes down to the conjoined cloacal structures: the right ureter is dilated at its lower end, while the left is unchanged in diameter.

The most striking feature of the abdominal arterial system is a large median vessel which at first sight appears to be the continuation of the dorsal abdominal aorta below the coeliac axis and superior mesenteric artery. This median artery arches forwards over the uterine part of the cloaca, deeply grooving it, and passes downwards in the middle line over the rudiment of the bladder. Immediately above the symphysis pubis it gives off symmetrical branches to each side of the pelvis, and thereafter bends upwards to enter the umbilical cord as the single umbilical artery (cf. Fig. 12).

That the dorsal abdominal aorta should assume such an unusual course and pass down on the ventral aspect of the viscera seemed so unlikely that a minute examination of the aorta was undertaken. As a result, the ventral vessel was found to be the larger of two branches into which the dorsal aorta divides. The smaller branch retains the dorsal position, and continues caudally upon the vertebral column to end in an arteria sacra media, after giving off distinct branches to the right and left sides of the pelvis.

In other words, the dorsal abdominal aorta instead of dividing at the level of the 4th lumbar vertebra into right and left common iliac branches, bifurcates at a much higher level, and gives off not lateral vessels, but a larger ventral branch and a smaller dorsal vessel. The latter provides small symmetrical pelvic branches identified provisionally with the proximal portions of the common iliac arteries. This condition resembles, in important particulars, that described above in specimen E.

It remains therefore to attempt to provide an explanation of the morphological value and status of the great ventral offshoot. This, as already remarked, terminates partly as the single umbilical artery, but not without giving off symmetrical right and left branches which pass around the true pelvic brim from the front of the bladder.

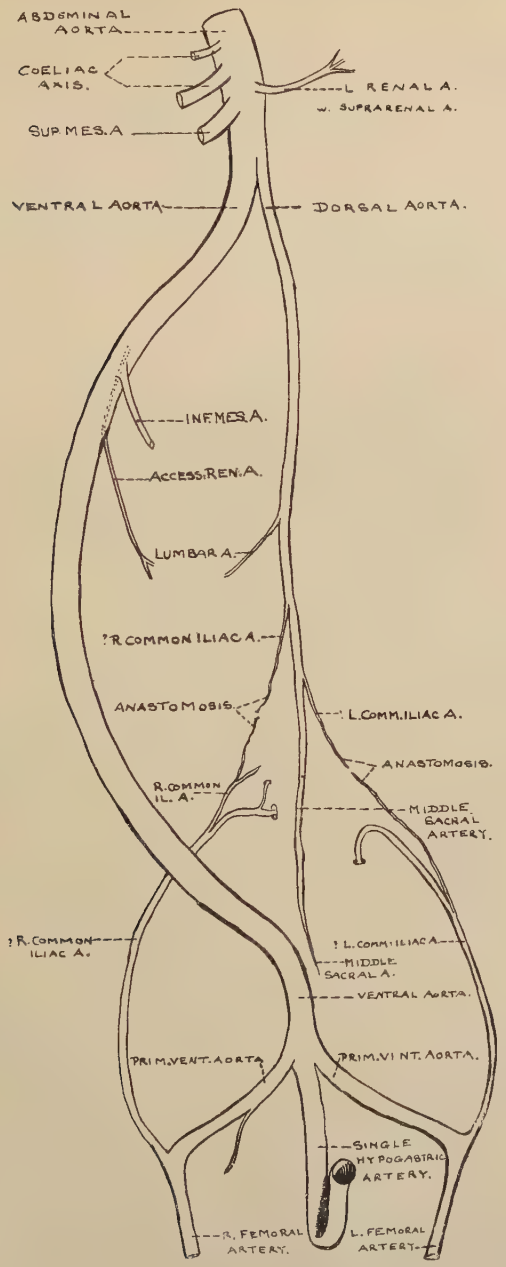


Fig. 12. Plan of the principal abdominal arteries of specimen F.

Each of these branches, after giving off a femoral branch at the appropriate point, is finally traceable to the back of the pelvic cavity and comes to an end in the close vicinity of the lateral terminal branches of the dorsal aorta. This suggests that the normal common iliac vessels in this instance have been interrupted.

The arrangement is represented in Fig. 12, and it should be remarked that the ventral and dorsal divisions of the aorta are separated by the kidneys (which touch in the middle line of the body) and by the pelvic viscera.

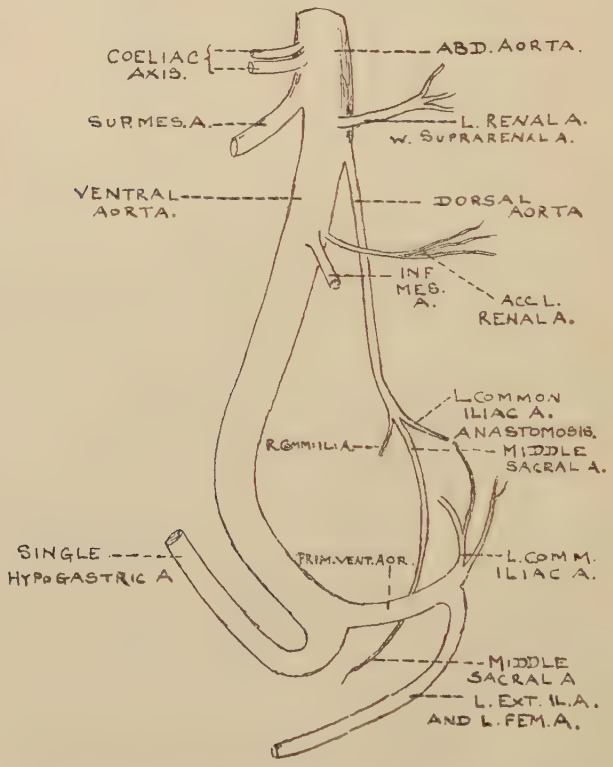


Fig. 13. The principal abdominal arteries of specimen F viewed from the left side.

Two veins are seen on the vertebral column in its lower portion. They are joined by a cross-branch below; then they diverge and the slender dorsal aorta appears between them.

Finally they unite to form the inferior vena cava. In a sense, therefore, two inferior venae cavae may be said to exist here.

The ground has now been cleared for gathering together the various pieces of evidence bearing upon the problem in hand. This is somewhat simplified by considering the connexions of the several arteries when viewed from one side only, as represented in Fig. 13. Ventral and dorsal divisions of the aorta diverge from their point of origin, but their terminal branches come into close proximity and probably anastomose in the region of the sacro-iliac synchondrosis. Such an arrangement is still more diagrammatically shewn in Fig. 14, which should be compared with the normal arrangement represented in Fig. 15.

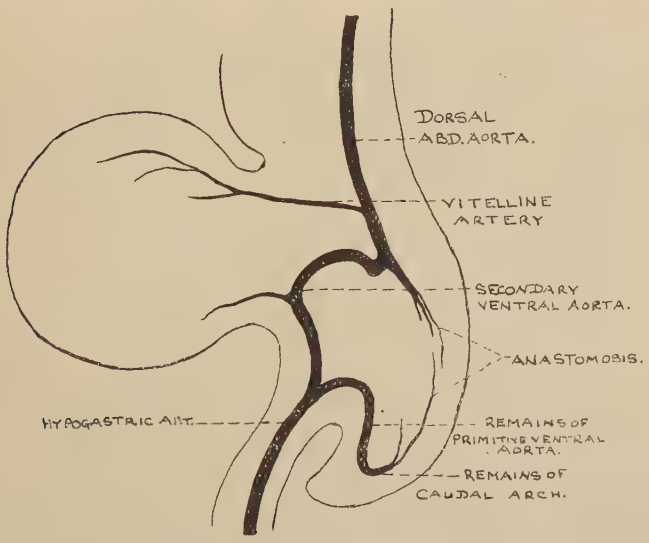


Fig. 14. Sketch to illustrate the interpretation of the abnormal arrangement of the abdominal arteries in specimen F.

My interpretation of the conditions found in specimen F is therefore that:

(*a*) The normal so-called secondary caudal arch has been interrupted on that side which is formed by the primitive dorsal aorta. The cause of the interruption is bound up with those which have determined the other malformations of the caudal end of the trunk and of the limbs.

(*b*) Concurrently with this interruption, an anastomosis has been opened up between a segmental splanchnic vessel (one of the omphalo-meseraic series), and one of the normal vitelline branches of the hypogastric artery. This anastomotic channel has been

enlarged so much as to have become the main path for the blood on its way to the placenta. Thus the origin of the large ventral artery becomes intelligible.

(*c*) These changes were bilateral, but the two symmetrical ventral vessels thus formed approached one another and fused along part of their length. The median position of the ventral aorta is thus explained.

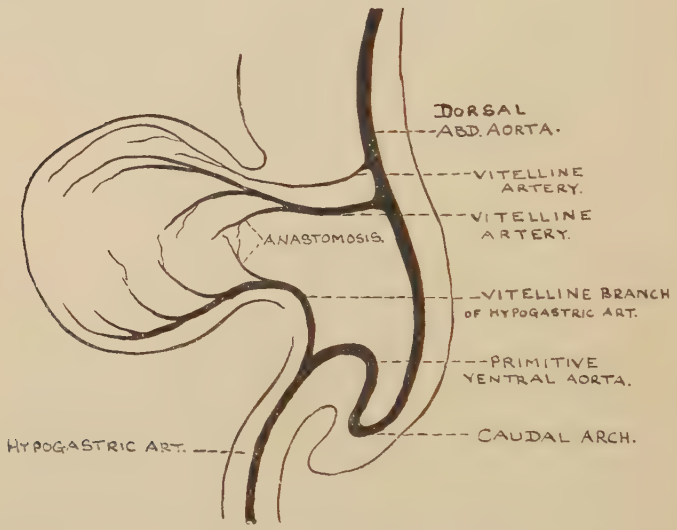


Fig. 15. Sketch (based on a drawing by Professor A. Robinson) of the arteries of the abdomen at an early stage in their normal development.

Should this interpretation be correct, it follows that the large ventral aorta has a complex nature. Near its origin it belongs to the series of segmental splanchnic vessels, of which the superior mesenteric artery and its branches are the most clearly recognisable representatives. In its lower parts, however, this ventral artery represents a persistent vitelline branch of the hypogastric artery continuous posteriorly with that part of the caudal arch termed the primitive posterior ventral aorta, from which the limb artery and the hypogastric artery are given off. In the intermediate portion of its course, the artery thus constitutes a channel of communication between a segmental splanchnic vessel and the primitive ventral aorta. Such a connexion has been observed in embryonic rodents (cf. Professor Young and Dr Robinson, *Studies in Anatomy*, from the Anatomical Department of the Owens College, Volume II, 1900, Plate I B, Fig. 18).

Finally, it may be repeated that fusion of bilaterally symmetrical vessels has occurred (cf. [*c*] supra).

Evidently this type of single umbilical artery is very different from that found in specimen A. If attention is now turned again for a moment to specimen E, it will be seen that the latter in this respect resembles specimen F rather than specimen A. The chief difference between specimens E and F may be explained by the reflexion that in E the malformation is less symmetrical than in F.

General review and Summary.

Two distinct types of the single umbilical artery are described in the foregoing paragraphs. In the first instance, one of the two normal hypogastric arteries has failed to develop, or has been completely suppressed, while the other one has become enlarged.

In the second type an entirely different history obtains, and the abdominal arterial system contains an abnormal vessel into the formation of which two elements have entered, viz. a segmental splanchnic artery, and the primitive ventral aorta. From this compound vessel the single umbilical artery is derived. In examples of the first kind the dorsal abdominal aorta remains unaffected, whereas in those of the second variety the dorsal aorta is of insignificant size. The effects upon the common iliac arteries are also different in the two cases. After drawing up this account and the conclusions based upon it, I found that Professor Weigert (in Virchow's *Archiv*, Band 104, p. 10), had already recognised a distinction between two classes of this anomaly. The reference to Professor Weigert's work I owe to the bibliography appended to a very admirable paper by Dr J. W. Ballantyne (in the *Edinburgh Obstetrical Transactions*, Vol. 23, 1897—98, p. 54). Any claim to originality in the present communication must therefore be based upon the more detailed explanation of the connexions of the several arteries concerned. I wish to record my indebtedness to Professor A. Robinson for useful hints in respect of this part of the work.

Professor Weigert's paper contains descriptions of three specimens. Of these, No. i. appears to have resembled closely my specimen A in respect of the arrangement of the abdominal arteries. Professor Weigert's second specimen agrees closely with my specimen F, though it is not clear to me whether No. ii. was symelian or not. Finally, Professor Weigert's specimen No. iii. must have been almost identical with my specimen E.

Dr Ballantyne's paper deals with the anatomy of a symelian monster. The arrangement of the abdominal arteries found therein very closely resembles that described above in specimen F. Dr Ballantyne rightly finding a difficulty in regarding the single umbilical artery of his specimen as a true hypogastric or allantoic derivative, put forward the view that in such cases the artery is of "vitelline" (or what I have termed segmental splanchnic) origin. I believe that I have shewn good reason for regarding such a view as only partly correct, and that the artery in question owes its origin to the dilation of an anastomotic channel originally connecting a segmental splanchnic vessel with a branch from the hypogastric offshoot of the primitive posterior ventral aorta (one of the piers of the secondary caudal arch).

A third category of the anomaly (viz. the single umbilical artery) is known. Herein the hypogastric arteries arise as usual, but converge as they pass over the bladder so as to meet and fuse just before they reach the umbilicus. This class is not associated with the grave malformations described in connexion with the preceding examples. Bardeleben (*Anatomischer Anzeiger*, Band x, s. 725) has described several instances in dissecting-room subjects.

In drawing up the foregoing account, I have not overlooked the writings of Hochstetter (*Morphologisches Jahrbuch*, Band xvi, 1890, and Hertwig's *Handbuch*, Band vi, s. 108), and of Tandler (*Anatomische Hefte*, xxiii, 1903), but I have found no reason for enlarging on the special points dealt with by those authors.

A few remarks may be added concerning the placenta. This has been described in comparatively few cases of symelian monstrosities, in which the single umbilical artery (presumably of the second and more complicated type) is known to be of frequent occurrence. Dr Ballantyne seems to have expected that the placenta would present abnormal features, although he recognised the possibility of the functional replacement of the normal umbilical arteries, by vessels of different morphological value. If my suggestion as to the nature of the single umbilical artery of symelian monsters is satisfactory, there seems no special reason for expecting the placenta to be structurally abnormal.

Dr Ballantyne noted a very remarkable and primitive condition of the abdominal veins in the symelian specimen described in his paper. The ductus venosus was not developed, for the umbilical vein terminated by breaking up into capillary offshoots in the liver. In my three specimens in which the umbilical artery is single, no such anomalous condition of the umbilical vein was discovered, for in each case the ductus venosus was formed.

Fig. 3. Specimen E, shewing deficiencies in the number of digits in both hands, and absence of the left foot.

Fig. 4. Skiagram of specimen E, shewing congenital absence of both radii, and of the left humerus. The right leg has been forcibly drawn into a position resembling that of the limb in normal cases.

Fig. 9. Oblique view of specimen F, from the right side.

Fig. 8. Back view of specimen F.

Fig. 7. Front view of specimen F.

I have seen an example of a symelian foetus accompanied by its placenta. No obviously abnormal characters could be detected in the latter. The specimen (which I estimate at the sixth to seventh month of development) is exhibited in the Hunterian Museum in London (Reference No. 302). That collection contains about ten symelian monsters, in one of which the viscera are inverted. In none of those shewn in the galleries is the arterial system of the abdomen exposed by dissection, though there is no doubt that such preparations would render the specimens more instructive than they are at present.

On the Fatigue of Metals subjected to Radium Rays. By J. A. Crowther, B.A., St John's College.

[*Read* 28 October 1907.]

Introduction.

The object of the following experiments was to discover if the continuous impact of radium rays upon a solid surface caused any diminution in the amount of secondary radiation emitted by it. It is well known that the amount of negative electricity discharged from a metal plate when exposed to the action of ultra-violet light, diminishes rapidly if the exposure to the rays is prolonged. Much work has been done on this subject, but the results obtained by different observers are so diverse that it still remains in some obscurity. There can be no doubt, however, that it varies

(i) for different metals,

(ii) with the gas in which the metal is placed,

(iii) with the quality of the ultra-violet light*.

It also depends upon the state of polish of the surface. A plate when fatigued can be restored to its original activity by careful re-polishing.

Large numbers of corpuscles are also given off from a surface exposed to the action of radium rays. It was thought of interest to investigate whether in this case also there were any phenomena of fatigue similar to those observed with ultra-violet light.

Experiments were performed using

(i) β and γ rays only,

(ii) α, β, and γ rays,

and extended over a considerable space of time.

Section 1.

In the first series of experiments, using only the penetrating β and γ rays of radium the apparatus employed took the form represented in figure 1. The rays from the radium R, fell upon a plate of the metal under investigation A, which was mounted upon a block of wood W, at an angle of 45° with the horizontal. The rays proceeding from the surface of the metal A,

* *Conduction of Electricity through Gases*, p. 288 (1906).

passed upwards into a cylindrical ionization chamber *B*, which was carefully screened from the action of the primary rays by thick lead blocks *S*, *S*. The current through the ionization chamber, was measured in the usual way, with a Wilson electroscope.

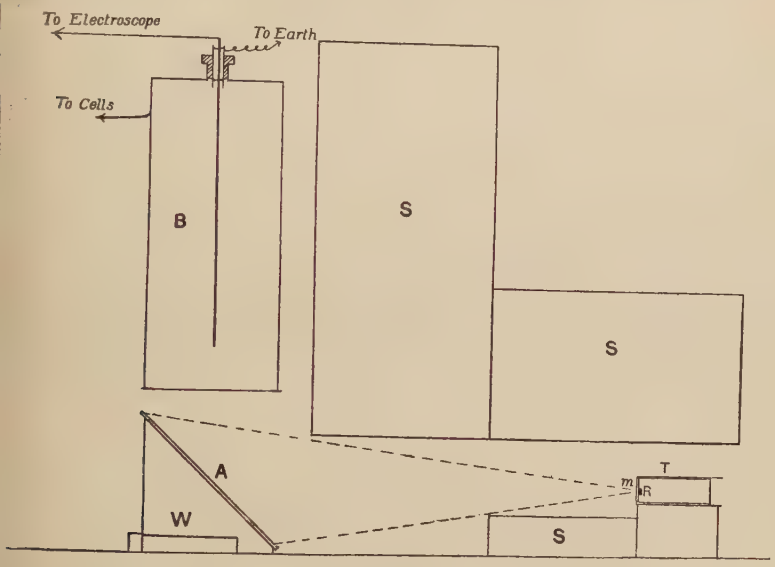


Fig. 1.

The radium was contained in a small depression in a brass cylinder, and was covered with a thin sheet of mica. This cylinder fitted into a brass tube *T*, the end of which was also covered with mica, and which was securely fastened in position on the bench. The block *W*, on which the exposed plate *A* was mounted, also moved between wooden guides, screwed down in position, on the bench. The radium and the plate could thus be removed and the plate exposed to the radium at a short distance; they could then be replaced again in exactly the same positions, for the purpose of measuring the secondary radiation. It was convenient to measure the radiation from *A* with the radium some distance away from the plate in order to allow sufficient space for the efficient shielding of the ionization chamber and electroscope, from the direct action of the primary rays.

The guides worked so well that the readings could always be recovered to well within $\frac{1}{2}\%$ if the radium and plate were both removed, and subsequently replaced.

The plate was exposed to the action of the rays at a distance of 4 cms. The measurements were made with the radium 25 cms. away from the plate.

The first experiments were made with a view to observing any rapid change that might occur in the secondary radiation from exposure to radium. Accordingly, the plate to be tested was mounted on the block *W*, and carefully polished, first with sand-paper, then with flour-emery, and finally, with a clean silk rag. The plates were of sufficient thickness to stop practically the whole of the β-rays, that is in general about 2 mm. The plate was placed in position under the ionization chamber and a reading made as quickly as possible after polishing. The plate was then exposed at close quarters to the radium, readings being made at frequent intervals during the rest of the day. The following table (Table I.) will give an idea of the nature of the results obtained. The first column gives the total length of exposure to radium in minutes; the second gives the rate of leak of the electroscope, in arbitrary units, and hence affords a measure of the secondary radiation from the plate, which in the particular case recorded below was of lead.

TABLE I.

Length of Exposure	Secondary Radiation
mins.	
15	100·0
40	100·0
72	100·6
86	101·0
110	100·9
192	100·8
210	100·4

It will be seen that the ionization in the chamber *B*, and hence the radiation from plate *A*, remained quite constant to within one per cent. during the whole course of the exposure. The experiment was repeated, in various ways, but always with the same result.

It was determined, therefore, to arrange for a continuous exposure to radium rays, for a prolonged period of time.

Accordingly a lead plate was carefully mounted and polished and the secondary radiation from it measured. It was then removed and exposed to the β and γ rays from the radium at a distance of only 4 cms. Readings were taken daily of the

secondary radiation, the plate and radium being replaced in proximity to each other, as soon as possible after each reading.

It was found that considerable fluctuations occurred in the values obtained from day to day. Corrections were applied to the leak in the ionization chamber B, for pressure and temperature variations, on the assumption that the amount of ionization in a gas produced by rays of given intensity was proportional to the density of the gas. Even so, however, the values obtained for the secondary radiation varied by as much as 5 °/₀ on different occasions, which was considerably more than the errors of reading. These fluctuations, which were probably due to atmosphere variations (possibly to changes in the humidity), were sufficient to mask any small change in the radiation from the plate A. It was necessary, therefore, to somewhat modify the method. Accordingly two exactly similar plates of the same metal were taken, and mounted in exactly the same way, on wooden supports, and carefully polished. The one plate, A_1 say, was exposed to radium after measuring the secondary radiation from it, in exactly the same way as before. The second, A_0, served as a standard plate, and was only exposed to radium radiation for a sufficiently long time to enable readings to be made of the secondary radiation from it, and then only at a considerable distance.

The secondary radiation from the two plates was compared immediately after polishing, and then at intervals of a few days, the plate A_1 being meanwhile exposed continuously to radium rays at close quarters.

TABLE II.

Date	Secondary Radiation		Ratio A_1/A_0
	Exposed Plate A_1	Standard Plate A_0	
Nov. 6th ...	105·6	98·0	1·077
Nov. 19th ...	104·6	97·6	1·072
Nov. 23rd ...	108·0	100·8	1·072
Nov. 28th ...	106·7	98·7	1·081
Dec. 12th ...	103·6	96·3	1·078
Jan. 11th ...	104·2	98·0	1·065
Jan. 23rd ...	100·0	93·9	1·066
Feb. 6th ...	104·2	97·8	1·068
Feb. 19th ...	104·4	97·9	1·070

The results obtained with lead plates are given in Table II. The plates were polished on Nov. 6th. The first column gives

the dates at which the two plates were subsequently compared, the second column, the amounts of secondary radiation from the plate A_1 continuously exposed to radium, the third column the secondary radiation from the standard plate A_0, and the last the ratio of secondary radiations from the two plates.

It will be seen that, although the separate values obtained for the secondary radiation vary somewhat erratically from time to time, the ratio for the two plates as given in the final column of the table remains very nearly constant indeed, the greatest discrepancy only amounting to about one per cent. There is not the slightest evidence that there has been any appreciable alteration in the amount of secondary radiation given off by the plate A_1, in spite of its having been exposed to the β and γ rays from radium, at a distance of only 4 cms. for a space of over three months.

The β and γ rays of radium having thus proved quite ineffectual to produce any fatigue in the secondary radiation from a metal plate, the experiment was now modified in order to enable the α-rays to be employed. The apparatus used is shewn in figure 2. The radium was spread uniformly over the bottom of

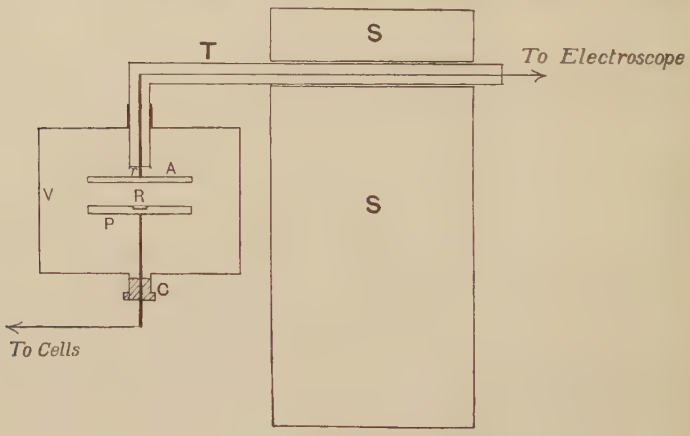


Fig. 2.

a shallow circular depression R, on a brass plate P, 4 cms. in diameter, and was covered in with a very thin piece of mica, in order to prevent the escape of emanation into the apparatus. The plates to be tested, were also 4 cms. in diameter, and 2 mm. in thickness, and screwed on to the rod r, by means of which they could be connected to a Wilson electroscope. The rod r, and the connecting wires, were enclosed in an earthed tube T, filled with sulphur, as air becomes too good a conductor when exposed to

radium rays. The electroscope itself, was shielded by thick lead blocks, *S*, *S* from the direct action of the radium rays. The plates *A* and *P* were placed about 0·5 cms. apart, and were protected by an outer earthed vessel *V*. *P* was supported on a rod passing out through an ebonite stopper *C*, and was charged to a high potential by a battery of storage cells.

The ionization between the two plates was very intense, and it was necessary to connect a condenser of considerable capacity to the gold-leaf system in order to reduce the rate of motion of the leaf to a measurable amount.

In this apparatus a copper plate was exposed, after careful polishing, to the α-rays from the radium bromide, continuously from March 22nd to May 3rd, a period of six weeks, readings being made of the ionization between the plates at frequent intervals during the period. The ionization is due to the combined effects of primary and secondary radiation. On account of the shortness of the range of the α-particle it was not found practicable to separate the two effects. However, as the primary radiation is constant, this is not a matter of importance, as any change in the total ionization must be due to a change in the secondary rays.

The observed ionizations were corrected for variations in temperature and pressure, but as described in the case of the β-rays (*supra*), the readings varied somewhat from time to time. These variations, amounting only to a few per cent., were quite irregular, and there was not the slightest indication of any alteration in the amount of secondary radiation from the copper plate. Thus calling the ionization on March 22nd 100, its value on April 16th was 100·2, and on May 3rd 100·8, or a difference of less than one per cent. As it is somewhat doubtful whether the α-rays produce any radiation which is capable of ionizing a gas, and as the ionization produced by the α-rays themselves is very large, it was feared that the effect due to the latter might be sufficiently large to mask any small alteration in the secondary radiation. In order to avoid this, the lower plate *P* was covered with 1/10 mm. of aluminium during the actual measurements of the secondary radiation, in order to cut off the α-rays. The radiation measured was, therefore, that due to β and γ rays only. The aluminium was removed immediately after taking the reading, and the exposure to α-rays continued.

Measurements were, however, also made of the ionization between the plates, without screening off the α-rays by aluminium. The results obtained, however, were very similar, and I was unable to detect any sign of fatigue.

We must, therefore, conclude that the prolonged exposure of a substance to either α, β or γ rays from radium does not produce

any alteration in the amount of secondary radiation given off by the substance under the action of these rays.

Section 2.

During the progress of the above experiments Prof. L. T. More, working in the Cavendish Laboratory, published a paper* in which he described some interesting cases of fatigue in the secondary radiation due to Röntgen rays, under the prolonged action of the rays. He shewed that for metal plates which had been allowed to age in air for some months after polishing, an exposure to X-rays for from one to three hours, caused a diminution in the secondary radiation which varied with the particular metal employed, but which was usually of about from 5% to 10% of its original value. With freshly polished surfaces there was in general an *increase* in the secondary radiation of a similar amount, if the plates were exposed to the continuous action of the rays.

It was considered of some interest to see if an exposure to radium produced a similar change on the secondary radiation set up by X-rays, as a prolonged exposure to the latter rays.

I was fortunately able to secure Prof. More's apparatus, which therefore served for the purposes of the following experiments also. The apparatus is fully described in Prof. More's paper. It is represented diagrammatically in figure 3. A, A' are two brass boxes, which serve as ionization chambers. Two plates, p_0, p_1, each 4 cms. in diameter and 2 mm. thick are made of the metal to be experimented upon, and placed in A, A' respectively, and connected by rods which pass out of the chambers through sulphur plugs, to two Wilson electroscopes, fitted up in the usual way for the measurement of ionization currents. The X-rays enter the boxes through circular openings ω, ω, and the ionization is measured between the plates p_0, p_1 respectively, and parallel wire gauze electrodes e, e, kept charged to a high potential by means of a cabinet of small storage cells. Each plate was connected to a separate electroscope, in order that the leak in the two chambers might be observed simultaneously. This was the only alteration made in the apparatus.

The plate p_0 served as a standard, and was not exposed to the fatiguing agent; p_1 was the test plate. The experiments were conducted as follows. The plates p_0, p_1 were placed in position as shewn in the diagram, and the ionization produced by the X-rays in the two chambers was measured. This ionization was shewn by Prof. More to be almost entirely due to the secondary radiation from the metal plate, that due to the primary rays

* *Phil. Mag.* June 1907, p. 708.

being practically negligible. The test plate p_1 was then exposed to the radium rays, at a distance of about $\frac{1}{2}$ cm., without removing

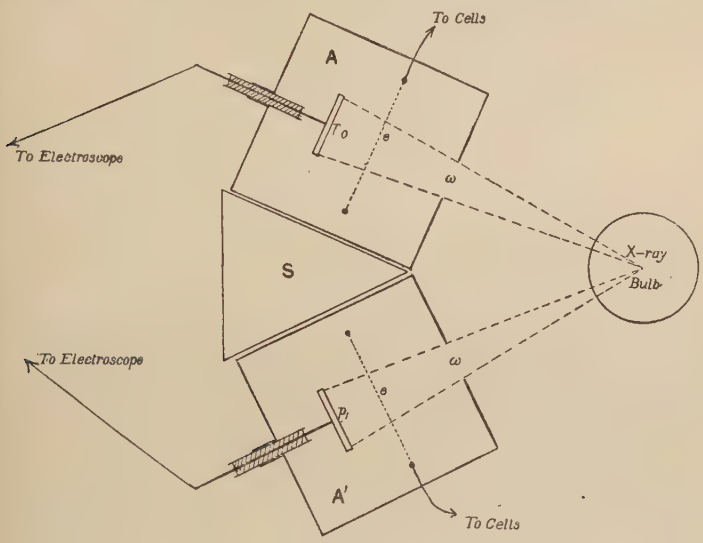


Fig. 3.

it from its position; the radium, in a suitable holder, being inserted between the plate and the gauze electrode. The exposure having continued for a given time, the radium was removed, and the secondary radiation produced by the X-rays for the two plates again measured. The standard plate p_0 was protected from the action of the radium by the walls of the boxes, which were of thick brass, and by the lead screen *S*.

The experiments were then repeated, using the X-rays as the fatiguing agent, as in the experiments of Prof. More; the standard plate being protected from the rays by a thick lead shutter placed in front of the window of the box.

The results obtained are given in Table III. The first column gives the length of exposure to the fatiguing agent in hours. The other columns give for the various metals tried, the ratio of the secondary radiation produced by X-rays from the test plate, to that produced from the standard plate, after the former has been exposed to one or other of the fatiguing agents for the times given in the first column.

It will be seen that the effects in the two cases are practically the same. In the case of polished zinc and lead, both X-rays and radium rays cause an increase in the secondary Röntgen radiation. For copper there is in both cases a slight decrease.

We must conclude, therefore, that radium rays produce in metals the same sort of fatigue of the secondary Röntgen radiation as is produced by the continuous application of the Röntgen rays themselves.

TABLE III.

Secondary Röntgen Radiation.

Exposure	Zinc		Copper		Lead	
	Radium	X-rays	Radium	X-rays	Radium	X-rays
hrs.						
0	100	100	100	100	100	100
1	104	—	98	98	—	—
2	106	104	—	—	103	105
3	—	—	97	98	101	101
4	109	106	—	—	101	—

SECTION 3.

Experiments were further made to discover if radium could produce or accelerate photo-electric fatigue; that is to say, if the rate of discharge of negative electricity from a metal plate under the action of ultra-violet light was altered by an exposure of the surface to the action of radium rays. The apparatus employed was that of the last section, the X-ray bulb being replaced by a source of ultra-violet radiation. As a compensation method of measurement was adopted it was not necessary to have the source of radiation particularly constant. An electric arc between two sharpened rods of aluminium was employed, and was maintained by the secondary of a transformer, the primary of which was connected directly to the alternating lighting circuit. This was found to give a copious but somewhat unsteady supply of ultra-violet rays.

The copper plates 4 cm. in diameter were carefully polished, with flour-emery, and finally with a clean silk rag, and placed in position in the two boxes; the wire gauge electrodes being charged to a high positive potential. The earth connections of the plates and the gold-leaf systems were broken, and the arc started. The rates of leak in the two chambers were measured by the movements of the gold leaves of the electroscopes.

The test plate p_1 was removed and exposed in a small vessel to a quantity of uncovered radium. It was thus exposed not

only to the α, β, and γ rays, but also to the emanation. The standard plate p_0 was also removed from the box, and placed in a similar small vessel, but without the radium.

After a definite time, the two plates were replaced in the boxes, and after a few hours had elapsed, to give time for the induced activity on the plate p_1 to die away, their rates of leak were again measured. It was found that the exposure to radium had greatly decreased the photo-electric effect of the test plate p_1.

The figures are as follows:

Copper.

Time of exposure	4 days
Ratio p_1/p_0 after polishing, but before exposure to radium	1·13
Ratio p_1/p_0 after exposure to radium for 4 days	·082
After repolishing p_1	1·20
After repolishing both p_0 and p_1	1·12

It will be seen from these figures, that the exposure to radium reduced the leak from the exposed plate p_1 to about 7 °/₀ of its original value, that is by more than 90 °/₀. The decrease in the leak from the standard plate p_0 in the same period, only amounted to a few per cent.

It will be seen also that the fatigue is entirely removed by repolishing the surface of the exposed plate.

On account of the importance of the result the experiment was repeated with fresh copper plates; but the results were exactly the same.

It was found further that it was not necessary to expose the plate to the radium emanation in order to produce these effects; but that photo-electric fatigue could be produced, to a smaller degree, by exposure merely to the β and γ rays from radium. Thus using copper plates the ratio of the leak from the test plate p_1 to that from the standard plate p_0 was found to be 1·12, immediately after polishing. p_1 was then exposed to the β and γ rays from radium, without being removed from the box. It was found that after two hours' exposure of p_1 to the radium rays the ratio of the photo-electric effects was reduced to 1·08, while after an exposure of six hours it was further reduced to 1·02. It appears, therefore, that photo-electric fatigue can be produced by the β and γ rays alone.

It is hoped to make further investigations on this point.

Conclusion.

The results of the preceding experiments shew:

(i) That the continuous impact of radium rays upon a metal plate does not cause any diminution in the amount of secondary radiation given out by the metal under the action of the rays themselves.

(ii) That the continuous impact of the radium rays upon a metal plate does produce an alteration in the amount of secondary radiation given out by the plate under the action of X-rays, and ultra-violet light.

(iii) That the fatigue so produced can be removed by repolishing the exposed surface.

These results would seem to suggest that the cause of "fatigue" is not any alteration of the nature of the material of the plate, but some kind of alteration, possibly in the magnitude of the "double layer" effect, at the surface of the plate.

The β and γ rays from radium penetrate a considerable distance into the metal, and even the α-rays penetrate to an appreciable extent. We should expect, therefore, that any alteration in the nature of the material of the plate would extend throughout a considerable thickness of material, in which case we should expect to get an appreciable alteration in the secondary radiation set up by the radium rays themselves. On the other hand, the secondary rays produced by radium rays, are very penetrating in character, and consequently the amount of them emerging from the plate would not be appreciably altered, by any alteration of the surface conditions. The secondary rays produced by Röntgen rays and ultra-violet light, however, are comparatively slow, and very easily absorbed. A difference in the surface conditions would, therefore, in their case greatly affect the amount of absorption, and consequently the number escaping from the plate. It is probably to their great penetrating power that the absence of fatigue in the case of the secondary radiation produced by the radium rays themselves, is due.

In conclusion, I wish to express my best thanks to Prof. J. J. Thomson, at whose suggestion these experiments were undertaken, for much kindly interest during the course of the work.

The Orientation of a Series of substituted Bromanilines.

By J. R. Hill, B.A., St John's College. (Communicated by Mr H. O. Jones.)

[*Read* 25 November 1907.]

The bromanilines dealt with in this paper were previously described in the *Proceedings* (Vol. xiv. 166). They are five in number and have the general formula $C_6H_4Br.N.(CH_3)(R)$, where R is an ethyl, propyl, isopropyl, isobutyl or isoamyl radical. In addition to an account of the preparation and properties of these amines and some of their derivatives, several attempts to determine the position of the bromine atom in the benzene nucleus were recorded. The methods employed, however, did not meet with much success and the constitution of only one of the compounds—namely the ethyl—was proved. It was first converted into the quaternary iodide $C_6H_4Br.(CH_3)_2.C_2H_5.N.I$ by the addition of methyl iodide. This was then treated with silver oxide, giving the quaternary hydroxide. On distillation the hydroxide underwent decomposition and the distillate deposited crystals on cooling. After several recrystallisations from alcohol the melting-point was 55° C. This decomposition product was shown to be dimethyl para-bromaniline (Weber, *Ber.* viii. 715, Wurster, *Ber.* xii. 1816 and 1820) by means of its melting-point of 55° and the quaternary iodide formed on addition of methyl iodide which melted at 200° C. Thus the bromine atom in the original methyl ethyl bromaniline must be in the para position.

Since this work was recorded the problem has been approached in other ways. In the first place dimethyl para-bromaniline (m.p. 55° C., Wurster, *loc. cit.*), prepared by the bromination of dimethyl aniline in acetic acid solution, was mixed with equivalent quantities of the iodides of the five alkyl radicals mentioned above. It was expected that the corresponding quaternary ammonium iodides $C_6H_4Br.(CH_3)(R)N.I$ would result; and then if these proved to be identical with the iodides prepared previously by the action of methyl iodide on the bromanilines, the bromine atom in the latter would be shown to be in the para position. This result, however, was not entirely realised.

The reactions were extremely slow in the cold except in the case of the ethyl iodide, where a solid was readily deposited. This solid, on examination, proved to consist not of *p*-bromphenyl dimethyl ethyl ammonium iodide, but largely of *p*-bromphenyl trimethyl ammonium iodide. The identity of this compound was established by its similarity in every respect to the quaternary

iodide obtained by the action of methyl iodide on dimethyl *p*-bromaniline: the melting-point of 200° C., higher than that of any of the other bromphenyl ammonium iodides, the crystalline form and the extremely small solubility in alcohol, all showed the two compounds to be identical.

The mixture of *n*-propyl iodide and dimethyl *p*-bromaniline gave a small quantity of quaternary iodide at the ordinary temperature, which on recrystallisation from alcohol had a melting-point of 170° C. It appeared to be identical with the compound formed by the action of methyl iodide on methyl propyl bromaniline, which also melts at 170° C. Consequently the latter has its bromine atom in the para position.

The mixture of isopropyl iodide and dimethyl *p*-bromaniline gave a small quantity of solid which has not been identified; and in the case of isobutyl and isoamyl iodides there was practically no action.

If heated to 100° C., the mixtures of dimethyl *p*-bromaniline and alkyl iodides deposited solid fairly rapidly. It was shown to consist largely of *p*-bromphenyl trimethyl ammonium iodide in every case.

This formation of the trimethyl compound appears to be due to the dissociation of ammonium salt into alkyl iodide and tertiary amine. The mechanism is probably somewhat thus:

$$C_6H_4Br.(CH_3)_2N + C_2H_5I \rightleftarrows C_6H_4Br.(CH_3)_2N.C_2H_5.I$$

$$C_6H_4Br.(CH_3)_2N.C_2H_5.I \rightleftarrows C_6H_4Br.CH_3.C_2H_5.N + CH_3I$$

$$C_6H_4Br.(CH_3)_2N + CH_3I \rightleftarrows C_6H_4Br.(CH_3)_3.NI$$

The trimethyl compound, being much more sparingly soluble than any of the other quaternary iodides which might be formed, will separate out and be removed from the sphere of action. This would account for its being the chief product of the reaction.

So far the constitutions of only two members of the series had been proved—the ethyl and the *n*-propyl compounds. Some other method of orientation had, consequently, to be looked for. A reaction was eventually discovered which enabled the whole series to be orientated.

It was found that if the quaternary iodides, obtained by the action of methyl iodide on the bromanilines and having the general formula $C_6H_4Br.(CH_3)_2(R)NI$, were heated with excess of methyl iodide in sealed tubes at 100° C., *p*-bromphenyl trimethyl ammonium iodide was produced. In some cases the action was almost complete after two hours heating. But in the case of the isoamyl compound the action was very slow, and it was at first thought that no trimethyl compound had been produced; however,

after prolonged heating with large excess of methyl iodide the trimethyl compound was detected. The isolation of the trimethyl compound from the other products of the reactions was readily effected; it is so very sparingly soluble that on cooling a hot alcoholic solution it crystallises out almost completely.

This replacement of alkyl radicals by methyl appears to be again due to the dissociation of ammonium salt into amine and alkyl iodide and the subsequent separation of the least soluble product. Thus:

$$C_6H_4Br.(CH_3)_2C_2H_5.NI \rightleftarrows C_6H_4Br.(CH_3)_2N + C_2H_5I$$

$$C_6H_4Br.(CH_3)_2N + CH_3I \rightleftarrows C_6H_4Br.(CH_3)_3NI$$

Each of the following five compounds were found in this way to give *p*-bromphenyl trimethyl ammonium iodide:

$C_6H_4Br.(CH_3)_2.C_2H_5.NI$	M. P. 189° C.
$C_6H_4Br.(CH_3)_2.C_3H_7$ (n) NI	M. P. 170° C.
$C_6H_4Br.(CH_3)_2.C_3H_7$ (iso) NI	M. P. 167° C.
$C_6H_4Br.(CH_3)_2.C_4H_9$ (iso) NI	M. P. 167° C.
$C_6H_4Br.(CH_3)_2.C_5H_{11}$ (iso) NI	M. P. 176° C.

The melting-point of this bromphenyl trimethyl ammonium iodide was 200° C., and in every other respect it resembled the compound obtained by the addition of methyl iodide to dimethyl *p*-bromaniline. Consequently the bromine atom is in the para position. Since each of the above series of five ammonium salts gives rise to para-bromphenyl trimethyl ammonium iodide on heating with methyl iodide, they are all para-compounds. They were obtained by the addition of methyl iodide to the corresponding bromanilines; consequently in the latter also the bromine atom is in the para position.

The decomposition and nitrification of sewage (1) *in alkaline solutions,* (2) *in distilled water.* By J. E. Purvis, M.A., St John's College, and R. M. Courtauld, M.A., M.B., Pembroke College.

[*Read* 25 November 1907.]

In a paper by Purvis and Coleman on "The influence of the saline constituents of sea-water on the decomposition of sewage*," the authors described a series of experiments to ascertain the influence of the chief salts found in sea-water, and also of sterilised and unsterilised sea-water, on the decomposition of sewage, and particularly with regard to the production of nitrates.

With regard to the principal salts, solutions of NaCl, $MgSO_4$, and $MgCl_2$ were made of such strengths as to be equivalent to the corresponding salts found in the water of the British Channel. Samples of Cambridge sewage were analysed for the amounts of free and albuminoid ammonias and of nitrates and nitrites already present; and they were then mixed with separate solutions of the salts so that each solution contained 1 per cent. of sewage. Similar quantities of sewage were added to a mixture of these three salts, and also to a normal sea-water obtained from Lowestoft and Stalham, off the Norfolk coast. The solutions were then allowed to incubate with free access of air and at a constant temperature, and they were analysed from time to time.

In order to compare our own tabulated results with theirs, we are enabled to give a table showing the results of an incubation of 1 per cent. sewage with a mixture of NaCl, $MgSO_4$ and $MgCl_2$, when analyses were made after 1 day, 2 days, 3 days, 5 days, and 8 weeks. The numbers represent parts per 100,000.

Time	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates and Nitrites
Commencement...	0·346	0·078	0·424	absent
1 day	0·980	0·550	1·530	,,
2 days.....	1·100	0·650	1·750	,,
3 days.....	1·130	0·650	1·780	,,
5 days.....	0·960	0·630	1·590	,,
8 weeks	0·950	0·360	1·310	,,

The results showed (1) that at first and until about the third day there was a rise in the total ammonia and then a gradual fall, and (2) that there was no appearance of nitrates and nitrites.

* *Journal Roy. San. Inst.* Vol. xxvii. No. 8 (1906), pp. 433—441.

In the following table we give the results when the sewage was incubated with sea-water from Stalham, off the Norfolk coast, when analyses were made after 1 day, 3 days, and 8 weeks.

Time	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates and Nitrites
Commencement...	0·32	0·12	0·44	absent
1 day	0·40	0·13	0·53	,,
3 days.....	0·36	0·17	0·53	,,
8 weeks	0·32	0·11	0·43	,,

The results were very similar to those in the preceding table, and showed (1) that there was a small rise in the total ammonia by about the end of the third day and then a gradual fall, and (2) that no nitrates or nitrites were produced.

And in all the experiments Purvis and Coleman conducted they obtained similar results. Perhaps the most striking result of the experiments was to prove that there was a marked interference in the production of nitrates and nitrites when the sewage was incubated with the aforesaid salts, both singly and when mixed in the proportions in which they are found in sea-water, and also when incubated with natural sea-water both sterilised and unsterilised. It appeared as if the dissolved salts interfered with the growth of the nitrifying organisms which, under favourable conditions, rapidly convert sewage into simpler compounds such as nitrates. The production of nitrates and the simultaneous disappearance of the two ammonias are usually considered to be measures of the efficiency of any method of sewage disposal. But in these experiments there was no production of nitrates or of nitrites. The decomposition of the sewage did not extend to a complete breakdown into the simple forms of water, carbon dioxide, and nitrates. There was a progressive decrease in the two ammonias, but highly complex nitrogenous compounds remained in solution even after a period of 8 weeks incubation.

It seemed to be of some importance to study the breakdown of sewage under other conditions than those of Purvis and Coleman's; and the present writers have conducted a series of experiments by incubating sewage (*a*) with alkaline solutions, and (*b*) with ammonia-free distilled water, of which the following is an account.

Experimental part.

The sewage samples were obtained from the Cambridge sewage farm. It was analysed for the amount of the free and albuminoid ammonias, nitrates and nitrites already present, and then mixed with (1) ammonia-free distilled water made faintly alkaline with soda solution, and (2) with distilled water alone, so that each solution contained 1 per cent. of the unfiltered sewage. The solutions were placed in Winchester bottles: the neck of each was loosely closed by a plug of cotton wool: and they were kept at a uniform temperature of about 15° C. The bottles and their contents were shaken from time to time, so as to aerate the contents very thoroughly. They were allowed to incubate, and their contents estimated from time to time. The two ammonias were estimated by Wanklyn's method, and the nitrites by means of meta-phenylene-diamine.

With regard to the estimation of nitrates, Purvis and Coleman used the indigo method, and they found they could detect nitrogen as nitrates added to sea-water in strengths not less than 0·005 parts per 100,000, but that the results were unsatisfactory in any proportions below this. In the present experiments we have used the zinc-copper couple method as described in full detail by Dr McGowan and his assistants*. It seemed as if the method would enable us to estimate smaller quantities of nitrates than the above. We closely followed the instructions in the Report, which are most clear and detailed. At the same time, and as mentioned by Purvis and Coleman in their paper, there is some possibility that such a couple not only would reduce the nitrates and nitrites to free ammonia, but that also other nitrogenous compounds, like the albuminoids, might be broken down into simpler forms, of which ammonia might be one. The final result would be that what ought to be considered ammonia derived from the reduction of nitrates and nitrites, is also ammonia produced from the decomposition of other compounds, and the figure obtained would be correspondingly high.

However, the aim of the following experiments is not to determine the smallest quantity of nitrate produced in any incubation of sewage, but to see whether the decomposition of sewage when incubated in a weakly alkaline solution and also with pure water compares with the results obtained by Purvis and Coleman when the sewage was incubated with saline solutions and with sea-water.

In the first and second series of experiments, the sewage was turbid, and the coarser particles in suspension were allowed to

* *Royal Commission Report on Sewage Disposal*, Vol. IV. Pt v. p. 17.

ettle, and the clear liquid was drawn from the top. One per cent. olutions in pure water were made for immediate analysis, and hen two 1 per cent. solutions were made, one of which was made aintly alkaline with soda solution (called alkaline solution) and he other of ammonia-free distilled water (called non-alkaline so- ution). The two ammonias, nitrates and nitrites, were estimated rom time to time after incubating for the several times mentioned n the following tables. The figures represent parts per 100,000.

Incubation	Alkaline solution				
	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates	Nitrites
SAMPLE I.					
Initial analysis	0·040	0·700	0·740	0·040	nil
2 days	0·304	0·320	0·624	0·008	trace
13 days.....	0·464	0·560	1·024	0·020	nil
52 days.....	0·704	0·160	0·864	0·023	,,
SAMPLE II.					
Initial analysis	0·524	1·040	1·564	0·069	nil
3 days	0·365	0·400	0·765	0·014	,,
17 days.....	0·636	0·500	1·136	0·019	,,
37 days.....	0·160	0·400	0·560	0·029	,,

Incubation	Non-alkaline solution				
	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates	Nitrites
SAMPLE I.					
Initial analysis	0·040	0·700	0·740	0·040	nil
2 days	0·370	0·560	0·930	0·098	trace
13 days.....	0·384	0·240	0·624	0·035	nil
52 days.....	0·264	0·440	0·704	0·088	,,
SAMPLE II.					
Initial analysis	0·524	1·040	1·564	0·069	nil
3 days	0·325	0·640	0·965	0·079	,,
17 days.....	0·369	0·800	1·169	0·039	,,
37 days.....	nil	0·160	0·160	0·092	,,

The more noticeable facts in the above tables are (1) smaller uantities of nitrates in the alkaline solutions than in the non- kaline; (2) a larger comparative increase of free ammonia in the

alkaline solutions than in the non-alkaline solutions, and (3) a progressive diminution in the total ammonias. The larger figures for the free ammonia in the alkaline solutions may be owing to the influence of the soda; and this corresponds to the results of Purvis and Coleman, who found that higher numbers were obtained in the artificial solutions of the salts incubated with sewage. It may be that the alkali breaks down the complex albuminoids with the production of free ammonia in larger quantities than in the non-alkaline solutions. Or, it may be caused by the more efficient action of certain organisms which notoriously carry on their work better in alkaline than in neutral solutions. Against the latter argument is the important fact that the nitrate figures are lower in the alkaline solutions, where there was a suitable base to fix the nitric acid as it was produced*. But, whatever be the explanation of these differences, the general results are comparable with the incubations with salt solutions

Incubation	Alkaline solution				
	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates	Nitrites
Sample III.					
24 hours	0·729	0·330	1·059	0·020	absent
48 hours	0·608	0·480	1·088	0·012	trace
72 hours	0·619	0·200	0·819	0·012	small
7 days	0·640	0·160	0·800	absent	trace
37 days.....	—	—	—	trace	distinct
49 days.....	—	—	—	0·021	trace

Incubation	Non-alkaline solution				
	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates	Nitrites
Sample III.					
24 hours	0·890	0·320	1·210	0·020	absent
48 hours	0·768	0·310	1·078	0·015	,,
72 hours	0·860	0·310	1·170	0·011	,,
7 days	0·880	0·210	1·090	absent	,,
37 days.....	—	—	—	,,	distinct
49 days.....	—	—	—	0·075	trace

* Boulanger and Massol have shown that ammonia inhibits the development of nitric-acid-forming organisms, but not their activity when once developed. *Annal. de l'Institut Pasteur*, XVII. and XVIII.

and with sea-water in so far as there is a slow and gradual decrease in the total ammonias: but that with regard to the production of nitrates there is some difference in that both in the alkaline and non-alkaline solutions there are definite, although very small, quantities of nitrates produced, which was not the case when the sewage was incubated with salt solutions and with sea-water, although the amount of nitrates in the alkaline solutions is considerably smaller than in the non-alkaline solutions.

The preceding tables (p. 358) give the results of a third series of experiments where sewage was incubated with an alkaline solution and with distilled water.

The incubations were continued for 37 and 49 days, and the nitrates and nitrites alone determined in these two later incubations.

The general results are similar to those of experiments I. and II., namely, (1) there were smaller quantities of nitrates in the alkaline than in the non-alkaline solutions, and (2) a progressive diminution in the total ammonias.

The following tables give the results of an earlier analysis made by Purvis and Coleman, when a sewage was incubated with distilled water, similar to the before-mentioned non-alkaline solutions.

Time	Free NH_3	Albuminoid NH_3	Total NH_3	Nitrates	Nitrites
Commencement...	0·32	0·12	0·44	absent	absent
1 day	0·48	0·16	0·64	trace	„
2 days	0·59	0·20	0·79	0·025	„
8 weeks	0·60	0·10	0·70	0·120	„

The results again show a development of nitrates and a slow decrease in the total ammonia figures, and they are comparable with the incubations in the above non-alkaline solutions.

General Conclusions.

On comparing these results, it is evident that the action of the salts in sea-water seriously interfered with the decomposition of any sewage poured into it. There was only a slow production of the two ammonias, although there was a progressive decline in the amount; and the nitrates were so small in amount that they must have been less than 0·005 parts per 100,000. And the present experiments prove that when sewage was incubated in slightly alkaline solutions there were definite amounts of nitrates produced: whilst there was a greater production when the incubations

were in distilled water alone. But the conditions for a large increase of nitrifying bacteria were obviously not so good as in artificial filter beds, and therefore a very large production of nitrates was hardly to be expected. It is of considerable interest to note that the action of the soda was in the same direction as the salt solutions and the sea-water, in that it interfered with the production of nitrates and nitrites. The incubations produced only a gradual breakdown of the various complex compounds in sewage, accompanied by very little nitrification: whilst in the salt and the sea-water incubations even this small quantity of nitrification was not produced. It is possible that if the incubations had been carried on long enough, the figures for the total ammonias might have disappeared, as there was a continual and gradual decrease. And, in view of this gradual decrease, and the absence of nitrates and nitrites, the only explanation to account for the disappearance of the nitrogen is that the decomposition was slowly carried on to the farthest point, and that nitrogen was given off as a gas. This explanation will need further investigations, for no complete experiments have hitherto been made in this direction, although Professor Letts has suggested the possibility of the production of free nitrogen gas in his evidence before the Royal Commission on the Disposal of Sewage. He states that in the Belfast experimental filter beds there was practically no nitrate in the effluent at all, although there was a great disappearance of free ammonia: and that in some of his experiments he could account for 20 per cent. of the total nitrogen which disappears as nitrogen in the free state*.

There can be little doubt, therefore, that the salts in sea-water do interfere with the development of useful nitrifying organisms whose normal action under proper conditions is to convert sewage into substances like nitrates. The smell often noticed when sewage is poured directly into the sea or an estuary appears to be caused by the presence of complex and varied organic compounds, which are only slowly and incompletely oxidised. But the final proof of the inhibition and disappearance of the nitrifying organisms is a bacterial one, and is a subject for future research.

The above investigation was carried on in the University Chemical Laboratory.

* *Royal Commission Report on Sewage Disposal*, Vol. II. Evidence, pp. 482, 483, pars. 8605—8610.

The influence of light and of copper on fermentation. By J. E. Purvis, M.A., St John's College, and W. A. R. Wilks, B.A., Gonville and Caius College.

[*Read* 25 November 1907.]

The action of light on various species of saccharomyces has been studied by different observers, and amongst these the researches of Kny and Lohmann are of some importance*.

The former placed the yeast in culture solutions in flat dishes, and exposed a part to the light of five gas flames, whilst the other part was in the dark, the heat rays being removed by filtering the light through water. His conclusion was that the *budding* of S. Cerevisiæ took place in moderate light with the same activity as in darkness.

Lohmann studied the action of both sunlight and the arc. He seeded cultures of S. Cerevisiæ on wort gelatine on glass slips, and exposed them to the action of a powerful arc lamp for eight hours. Above a temperature of 18° C. he found that the budding was retarded in the cultures subjected to the light. The same yeast was seeded on agar agar plates, and exposed to the action of sunlight, when the yeast was killed after several hours. He also noticed that even diffused daylight had a retarding influence on the budding of the cultures, but that this only occurred after prolonged exposure to the light.

The influence of light and various spectral colours on the sporulation of saccharomyces has been studied by Purvis and Warwick†. They observed that the red rays accelerated the formation of spores more quickly than white light and more quickly than when the development took place in the dark: that the green rays retarded the development: that the blue and violet rays retarded the sporulation still more: and that the ultra-violet rays were still more effective, and that they influenced the vitality of the cells detrimentally when the latter were exposed to the influence for some time.

It appeared to be of some interest to study the effect of light during a normal fermentation of hopped wort and other fermentable solutions, and the following notes describe the results of a comparative study of the influence of light and of various spectral colours upon fermentation when conducted in (*a*) unsterilised copper vessels, (*b*) sterilised glass vessels, and (*c*) in unsterilised

* *Traité de Microbiologie*, Duclaux, Vol. III. pp. 289—291; Kny, *Ber. d. botan. Gesells.* 1894, Heft 3; Lohmann, *Inaug. Dissertation*, Rostock, 1896.

† *Proc. Camb. Phil. Soc.* Vol. XIV. Pt 1, pp. 30—40.

glass and copper vessels. The effects of the influences were traced in determinations of the optical activity, the copper oxide reducing power, the nitrogen content, the acidity, and the specific gravity of the distilled fermented solution (and therefore the amount of alcohol produced). The temperature of the fermenting wort was noted from time to time.

Description of the Apparatus.

In the first series of experiments there were four copper vessels, and one side of three of these was replaced (1) by ordinary glass, (2) by red glass, (3) by an ammoniacal solution of copper sulphate; whilst, for the experiments in the dark, a copper vessel of the same size and volume as the first three was used. As regards the first three vessels they were arranged with the glass sides facing a fairly large incandescent light, the red glass copper vessel a little further away than the other three, and they were covered with loosely fitting lids. The four vessels, and the central light, were covered with thick black cloth so as to exclude any external light. The time during which the fermentation was allowed to proceed varied from 4 to 7 days.

The nitrogen determinations were by Kjeldahl's method; the specific gravities by a specific gravity bottle; the optical activity by a three shadow polariscope; the copper oxide by reduction of the oxide by hydrogen in small glass tubes and weighing the copper produced. In determinations of the acidity, 50 c.c. of one of the fermented solutions were made up to a definite volume, 4 c.c. of litmus solution added, and $\frac{N}{10}$ alkali until, as far as could be roughly judged, neutralisation was complete; 50 c.c. of this solution were then placed in a Nessler cylinder. Fifty c.c. of the other solutions made up to the same volume as before were then neutralised until on taking out 50 c.c., the same tint was observed as the original 50 c.c. The method was also used in the nitrogen determinations, and it gave most satisfactory results.

As regards the temperature observations, we only give the details in the second series of experiments, and merely note the average temperatures in the others. In the determination of the other constituents we give the mean of two separate experiments.

Sterilised hopped wort was used in the series of experiments A. and C.: whilst a specially prepared fermentable solution was used in the series of experiments B. (p. 369).

Details of the Experiments.

A.

I. Equal volumes of hopped wort were placed in the four vessels and allowed to ferment under the influence of ordinary English yeast. The analysis of the unfermented wort gave: copper oxide reducing power of 20 c.c. of a 5 °/₀ solution = 0·189 gm Cu. The optical activity at 15° C. for 100 °/₀ wort = + 17·68°.

The N. content; 50 c.c. of $\frac{N}{10}$ H_2SO_4 were used, and 42·7 c.c. of $\frac{N}{10}$ NaHO were required to neutralise excess after Kjeldahling 10 c.c. of the wort.

The temperature on starting the fermentation was 15·5° C., and the average temperatures between 24 April at 2 p.m. and 27 April at 9.30 a.m., were:

dark = 22·6° C.
white = 23·2 „
red = 22·9 „
blue = 22·4 „

After the fermentation the following results were obtained.

(1) Optical activity for 100 °/₀ solution at 15° C.:

dark = + 14·10°
white = + 7·98
red = + 8·08
blue = + 7·86

The number for the dark is high and comparable with that of the original wort. It may be the result of the action of acidifying organisms growing very rapidly; and at the rather low starting temperature the resultant acid dissolving a little copper of the vessel, and thereby influencing detrimentally the growth of the yeast. In the remaining experiments the wort was previously warmed to a temperature higher than 15° C.

(2) Copper oxide reducing power—20 c.c. of a 5 °/₀ solution gave:

dark = 0·1580 gm. Cu.
white = 0·1345 „
red = 0·1930 „
blue = 0·1895 „

It is noticeable that the copper oxide reducing power is comparable with the optical activity, with the exception of the white light. The discrepancy is not quite explicable, for in the remaining experiments, the white light ones are quite normal and comparable.

(3) Specific gravity:

dark = 999·49
white = 992·22
red = 992·52
blue = 993·99

The specific gravities show differences which are not so marked as in the later experiments; and this may be due to the rise in temperature in the red being much more rapid than in the blue and the dark, owing to the absorption of the red rays; the bacteria have then much less chance of active development in the blue and in the dark, than in the red.

The acidities and the nitrogen contents were not determined.

II. The following is the analysis of the unfermented wort.

The optical activity for 100 °/₀ solution = + 24·34°.

The copper oxide reducing power of 20 c.c. of a 5 °/₀ solution = 0·222 gm Cu.

The nitrogen content; 25 c.c. $\frac{N}{10}$ H_2SO_4 were used and 13·7 c.c. of $\frac{N}{10}$ NaHO were required to neutralise the excess after Kjeldahling 10 c.c. of the wort.

The wort was pitched on April 30 at 4 p.m. and as an example of the changes in temperature during the fermentation, the following table gives details of the readings.

	dark	white	red	blue
May 1, 10 a.m.	22·25° C.	22·25° C.	22·75° C.	22·00° C.
„ 2 p.m.	26·75	26·00	27·25	26·00
May 2, 10.30 a.m....	23·25	22·75	23·50	23·25
„ 4 p.m.	24·75	23·50	23·75	24·25
May 3, 11 a.m.	23·00	23·00	23·75	23·50
„ 3 p.m.	23·60	24·00	24·75	24·10
May 4, 9 a.m.	22·75	22·25	23·50	23·00

The average temperatures throughout the fermentation were:

dark = 23·8° C.
white = 23·4 „
red = 24·2 „
blue = 23·7 „

The higher temperature in the red as compared with the others is to be noted.

The fermentations were stopped on May 4 at 9.30 a.m. The one in the red and the dark had marked ethereal odours. The white was less so, and the blue hardly at all. The following results after the fermentations were obtained:

(1) The optical activity for 100 °/₀ solutions at 15° C.

dark = + 7·86°
white = + 6·94
red = + 7·32
blue = + 6·54

(2) The copper oxide reducing power in 20 c.c. of a 20 °/₀ solution gave:

dark = 0·1170 gm. Cu.
white = 0·0980 „
red = 0·1015 „
blue = 0·0860 „

(3) The specific gravity gave:

dark = 987·40
white = 987·39
red = 987·11
blue = 987·13

(4) The nitrogen content; 10 c.c. of each of the fermentations were used in the Kjeldahl method and 25 c.c. $\frac{N}{10}$ acid used to neutralise the NH_3 distilled. The number of c.c. of $\frac{N}{10}$ acid required to neutralise the NH_3 were:

dark = 7·95 c.c.
white = 8·00 „
red = 7·85 „
blue = 7·95 „

These numbers appear to prove that there is little or no effect upon the nitrogen assimilation or solution.

(5) The acidity. The following numbers represent the number of c.c. of $\frac{N}{10}$ alkali used in the neutralisation.

dark = 13·6 c.c.
white = 13·8 „
red = 15·1 „
blue = 13·7 „

III. The following is the analysis of the unfermented wort.

Optical activity for 100 °/₀ solution = + 6·96°.

The copper oxide reducing power for 20 c.c. of a 20 °/₀ solution = 0·197 Cu.

The nitrogen content; 25 c.c. of $\frac{N}{10}$ H_2SO_4 were used and

21 c.c. of $\frac{N}{10}$ NaHO were required to neutralise the excess after Kjeldahling 10 c.c. of the wort.

The wort was pitched on May 6, and the average temperatures between May 7 at 10 a.m. and May 11 at 9 a.m. were:

dark = 23·8° C.
white = 24·0 „
blue = 23·9 „

The fermentation in the red was not continued owing to an accident.

The following numbers give the results of the analysis of the various fermentations:

(1) Optical activity for 100 °/₀ solutions at 15° C.

dark = + 2·10°
white = + 2·37
blue = + 2·31

(2) Copper oxide reducing power in 20 c.c. of 50 °/₀ solutions:

dark = ·0725 gm. Cu.
white = ·0970 „
blue = ·0660 „

(3) Specific gravity:

dark = 997·88
white = 998·23
blue = 997·94

(4) The nitrogen content; 10 c.c. of each fermentation was Kjeldahled, and the NH_3 distilled into 25 c.c. of $\frac{N}{10}$ acid. The following numbers represent the amount of $\frac{N}{10}$ alkali used to neutralise excess of acid:

dark = 22·95 c.c.
white = 23·60 „
blue = 23·37 „

(5) The acidity. The following numbers represent the amounts of $\frac{N}{10}$ alkali required to neutralise 50 c.c. of each of the various fermentations:

dark = 7·77 c.c.
white = 12·47 „
blue = 6·20 „

The small development of acidity in the dark and blue is very marked.

IV. The following is the analysis of the unfermented wort.

Optical activity for 100 °/₀ solution = + 28·6°.

Copper oxide reducing power in 20 c.c. of a 20 °/₀ solution = 1·052 gm Cu.

The nitrogen content; 25 c.c. of $\frac{N}{10}$ H_2SO_4 were used and 13·5 c.c. $\frac{N}{10}$ NaHO were required to neutralise the excess after Kjeldahling.

The wort was pitched on May 13 at 5 p.m., and the average temperatures between May 14 at 9 a.m. and May 20 at 9 a.m. were:

dark = 23·4° C.
white = 23·6 „
red = 23·4 „
blue = 23·3 „

The following gives the results of the analyses of the various fermentations:

(1) Optical activity for 100 °/₀ solutions at 15° C.

dark = + 5·97°
white = + 4·60
red = + 4·93
blue = + 8·08

(2) Copper oxide reducing power in 20 c.c. of 20 °/₀ solutions:

dark = 0·217 gm. Cu.
white = 0·148 „
red = 0·159 „

(3) Specific gravity:

dark = 987·80
white = 987·38
red = 987·38

(4) The nitrogen content; the numbers represent the c.c. of $\frac{N}{10}$ NaHO required to neutralise excess of acid after the distillation of the NH_3 by the Kjeldahl process:

dark = 17·07 c.c.
white = 17·92 „
red = 17·70 „

(5) The acidity. The following numbers represent the amounts of $\frac{N}{10}$ alkali used to neutralise 50 c.c. of each of the fermentations:

dark = 13·6 c.c.
white = 14·4 „
red = 14·5 „
blue = 31·35 „

In this IV. series, a small leak was noticed in the cell containing the blue solution, so that a little of the copper sulphate was mixed with the wort. The copper sulphate appeared to inhibit the action of the yeast very greatly as is seen from the optical activity numbers. The bacteria, however, were not affected to the same extent, for the acidity in the blue instead of being less than in the others was more than twice as great. The increased amount of acid would attack the copper vessel, the development of the yeast would be inhibited to a greater extent than the bacteria, and consequently the acidity would be greatly increased.

But the general results and the effects are comparable with those of the wort II. They were both rich worts.

V. The unfermented wort gave the following analysis.

Optical activity for 100 °/₀ solution = + 11·43°.

The copper oxide reducing power and the nitrogen content were not determined.

The wort was pitched on May 23 at 4 p.m. and the temperature was 21°. And in addition to the four fermentations in the copper vessels, there was also an additional fermentation in a glass beaker under the influence of white light. The average temperatures between May 23 at 5.30 p.m. and May 28 at 9 a.m., were :

dark = 24·4° C.
white = 24·7 „
red = 24·7 „
blue = 24·9 „
white (beaker) = 24·7 „

The following are the results of the analyses of the fermentations :

(1) Optical activity for 100 °/₀ solutions at 15° C.

dark = + 5·15°
white = + 5·10
red = + 5·00
blue = + 5·13

(2) Specific gravity :

dark = 991·43
white = 991·82
red = 991·34
blue = 991·19

(3) Acidity. The numbers represent the amounts of $\frac{N}{10}$

alkali used to neutralise 50 c.c. of each fermentation:

dark = 20·85 c.c.
white = 23·80 „
red = 13·60 „
blue = 12·05 „
white (in glass beaker) = 12·90 „

The great diminution in the acidity when the fermentation was carried on in the glass vessel compared with the corresponding experiment in the copper vessel, and under the influence of white light, is noticeable.

B.

In the second series of experiments, the fermentations were carried on in sterilised glass vessels, and the fermenting solutions were not of ordinary hopped wort, but contained:

10·00 °/₀ glucose
0·15 °/₀ ammonium sulphate
0·15 °/₀ ammonium phosphate

Of this solution 150 c.c. were used in I. series of experiments, and the same volume diluted to about one half the strength in the II. series of experiments. The experiment marked I A was conducted in a non-sterilised glass vessel open to the air, and the result showed that the carbon dioxide could easily escape from the other vessels, so that there was nothing to be feared from its action. The other glass vessels were loosely covered with glass wool, through which thermometers passed into the fermenting wort. The light was filtered through red glass plates for the red rays and through ammoniacal copper solutions for the blue rays, and the effect was compared with the direct effect of white light and with one guarded from contact with any light by the vessel being covered with black cloth. Pure cultures of S. Cerevisiæ I. were used to ferment the nutrient solutions.

The optical activity of 100 °/₀ of the original solutions was = + 10·01°. The average temperatures of the series of fermentations between May 28 at 11 a.m. and June 3 at 9 a.m., were:

I.	dark = 23·7° C.	II.	23·3° C.	I A.	22·9° C.
	white = 23·3 „		23·6 „		
	red = 23·7 „		23·7 „		
	blue = 23·3 „		22·9 „		

After the fermentations, the following numbers were obtained for the optical activities:

I.	dark = + 2·34°	II.	+ 1·85°	I A.	+ 2·35°
	white = + 2·35		+ 1·82		
	red = + 2·28		+ 1·81		
	blue = + 2·35		+ 1·81		

C.

In this series of experiments, four were conducted in unsterilised glass vessels and two in unsterilised copper vessels, using only red and white light for the latter. The optical activity of a 100 °/₀ solution was about + 16°.

The average temperatures between May 30 at 10.30 a.m. and June 3 at 9 a.m. were:

I. Glass vessels	II. Copper vessels
dark = 21·4° C.	white = 22·3° C.
white = 22·3 „	red = 22·0 „
red = 22·3 „	
blue = 21·3 „	

The values of the optical activities after the fermentations were:

I. Glass vessels	II. Copper vessels
dark = + 3·42°	white = + 4·94°
white = + 3·48	red = + 7·61
red = + 3·36	
blue = + 3·43	

The numbers obtained from the fermentations in the glass vessels do not show very great differences, whereas those obtained from the copper vessels are very marked. The great difference between the numbers obtained from the copper vessels compared with those of the glass vessels is also very noticeable.

The values of the acidities after fermentation were the following; the numbers represent the amount of $\frac{N}{10}$ alkali required to neutralise the acid produced:

I. Glass vessels	II. Copper vessels
dark = 12·3 c.c.	white = 57·4 c.c.
white = 12·5 „	red = 81·3 „
red = 13·3 „	
blue = 23·8 „	

The fermentation in the blue light can hardly be compared with the others because the temperature was very low (only about 19°) for a long time, and this probably affected the vitality of the yeast, so that bacterial action became stronger. The numbers obtained from the copper vessels were also very high, and may be explained by the fact that the wort had remained corked up in a bottle for a day; and, although, from the smell, there was no apparent acidification, it is probable there was a development of acid producing bacteria. The acid would dissolve a little of the copper, and thereby retard the action of the yeast.

D.

From a consideration of the results of the fermentations in sections A., B. and C. it seemed to be desirable to conduct another series of fermentations in the four copper vessels, in order to discover what amount of copper, if any, was dissolved during the process of the fermentation. And, for this purpose, a litre of hopped wort was placed in each of the vessels, and the fermentations went on for five days under exactly the same conditions as those described in the preceding experiments. At the end of this time, the liquors were filtered, evaporated to dryness, and the residues ignited until all the organic substances were burnt away. What remained was dissolved in acid, and the CuO estimated in the usual way. Owing to an accident, the residue of the fermentation in the red light was lost; but the following numbers show the amounts of CuO obtained from the three others, in percentages of the original wort:

dark = 0·0072 % CuO
white = 0·0051 „
blue = 0·0052 „

There can be little doubt, therefore, that the observed differences in the numbers obtained when the fermentations went on in the copper vessels were due to the solution of a little of the copper influencing the action of the yeast. And it is of interest to note the smaller quantity of CuO found in the fermentations in the white and blue than in the dark.

General Results.

The more important results of the preceding experiments are:

(1) That fermentation when carried on under sterilised and unsterilised conditions in glass vessels, and under the influence of various spectral colours as well as of white light and also in the dark, was not seriously influenced, as shown by determinations of the optical activities of the fermented solutions. The small differences in the numbers and particularly of the acidities may be owing to experimental errors. Further experiments will be necessary to confirm these differences, and with a stronger light, like that of the arc.

(2) That fermentation when conducted in copper vessels, but otherwise under the same conditions, is influenced very considerably, as shown by the marked differences in the numbers obtained from the acidity, optical activity, &c. It is not suggested that this influence was caused by rays of light of varying degrees of refrangibility, except indirectly. It appears that copper dissolved

from the fermenting vessels largely determined the course of the fermentations. For example, the results obtained under the influence of blue light prove that the inhibitory effect of this light on the development of acidifying bacteria, was to decrease the amount of acid produced in the fermenting wort, and, therefore, to lessen the amount of copper dissolved. On the other hand, the fermentations under the influence of red light and in the dark gave better facilities for a more vigorous growth of these bacteria. The acid produced thereby, dissolved a little of the copper; and its inhibitory effect on a normal growth of the yeast, and a regular fermentation, is evident from the varying numbers obtained in the different determinations. The larger amount of CuO obtained in the fermentation in the dark as compared with the others appears to be evidence in favour of this view. But contributory causes may be owing to the differences of temperature; for the temperature of the fermentations in the dark and the red were usually a little higher than in the blue, and the solvent action of the acid on the copper would be thereby increased. At the same time it is probable that, as the fermentations proceeded, the CO_2 produced from the break down of the sugar, would also dissolve a little of the copper, and this also should be added as a further influence.

(3) Another fact which is indicated by these experiments is the influence of the original composition of the wort. In a good wort, the yeast appeared to resist the action of the copper better than in a poor wort; for the differences in acidity, &c., are much less marked in the good worts than in the poor ones.

In view of these varying results, it will be of importance to study more systematically the influence of different amounts of copper, and of other metals like silver, upon the growth of yeast and fermentation, a problem which has been kindly suggested by Dr Horace Brown, who called our attention to some experiments conducted at Rothampstead on the influence of small quantities of copper and silver on the growth of various plants.

The above investigation was conducted in the University Chemical Laboratory.

Sexual Phenomena in the Free-living Nematodes. (Preliminary note.) By F. A. Potts, B.A., Trinity Hall.

[*Read* 11 November 1907.]

Attention has been drawn by Maupas[1] to the remarkable sexual conditions which occur in the free-living nematodes *Rhabditis* and *Diplogaster*. While some species of these two genera are bisexual, males and females occurring in equal proportions, others are composed of self-fertilising hermaphrodites, whose genital gland produces, first spermatozoa, then eggs which are fertilised by the male gametes as they pass one by one into the uterus. Large cultures of nematode species of this latter class are found to contain occasional male individuals, but though these possess a complete spicular apparatus for copulation and produce large quantities of spermatozoa, they are sexually inactive and entirely superfluous in the economy of the species.

Maupas regards these supplementary males as the remnants of the whole male sex, while the hermaphrodites of the same species represent the female sex, from which they are derived by the substitution of a functional hermaphrodite gonad for the ovary, thus rendering the agency of the male sex unnecessary in reproduction. The occasional reappearance of males is correlated with the incompleteness of the hermaphroditism. In all species studied it was found that there was an insufficient production of spermatozoa in the individual; when this stock was exhausted the animal continued to lay unfertilised eggs which degenerate. Maupas was also able to describe species in which the hermaphroditism was incipient; in one horn of the genital gland spermatozoa and consequently fertilised eggs were produced, while in the other the gland was purely female and unfertilised eggs only were traced back to it. In such nematodes the percentage of supplemental males though low was markedly higher than in the species where hermaphroditism was more complete. The object of the present communication is to set on record a confirmation of that part of Maupas' results summarised above.

Free-living nematodes, of the two genera mentioned before, exist wherever sufficient nutrition can be obtained from decaying organic matter. Many species have been found in samples of vegetable mould from various localities, the method of obtaining them in quantity being to expose pieces of meat on the surface.

[1] "Modes et Formes de Reproduction des Nématodes," *Arch. Zool. Exper. et Gen.* T. 8, 1900, pp. 463—624.

On decay these are found to contain thousands of living and breeding nematodes.

The hermaphrodite species occur in my experience at least as frequently as the bisexual forms, and in general are easily adaptable to culture methods. Solutions of peptone were adopted as convenient culture media; while allowing close observation of the processes of development, they constitute so favourable an environment for growth that the whole duration of a generation is only from ten days to a fortnight. It is, however, only the putrefaction products of the peptone on which the nematodes thrive so well; in sterile solutions growth is suspended and oviposition proceeds only with great slowness.

The species under observation were mostly inedited; there can be little doubt that the researches of Bastian, Schneider, de Man, etc. have not revealed a tithe of the species of free-living nematodes. The most extended series of observations was made on a hermaphrodite species of *Diplogaster*, which strongly resembled a bisexual species described by earlier authors. It may, perhaps, be suggested that in the future complemental pairs of species may be found to exist, the bisexual form and the hermaphrodite derived from it.

In the course of research single individuals were, as far as possible, isolated in each generation and the constitution of their progeny examined. It is considered that these precautions not only prove that the supplemental males really belong to the species and are not merely due to accidental infection with bisexual species, but also render possible an exact analysis of the proportions of the sexes.

The supplemental males occurred throughout the cultures and could be recognised as belonging to the same species as the hermaphrodite form, by the structure of the buccal cavity. They possessed a copulatory bursa and spicules, fully formed and of an identical type in all those examined. Not only did their structural organisation appear perfect, but they were observed to be capable of even more energetic movement than the hermaphrodites. But though the genital gland and duct was packed with spermatozoa in various states of development, which, when mature, exhibited amoeboid movements (and were thus apparently capable of the work of fertilisation), the males seemed to have lost their sexual instinct. This "psychical decadence" of the males, as Maupas phrases it, though marked, was not complete, for one out of the many whose behaviour with hermaphrodites was observed was seen in copulation. It was concluded, however, that the results of such union must, in the present case, always be unfruitful and that the males are an entirely unnecessary factor in the reproduction of this nematode.

The cultures produced males in constantly small but fluctuating numbers. There were many cases where several generations passed before the appearance of a single male, in a whole series of cultures. These cases, in which the highest percentage of males were observed, may be exemplified by a culture where four males and 60 hermaphrodites were counted. In no case was it found possible to obtain by selection a strain producing a high proportion of males. Artificial alterations in the environment apparently made no difference to the sex proportions. Unfavourable conditions were brought about by dilutions of the peptone-solutions and by crowding, but these brought about no increase in the numbers of the males.

It may be suggested that the origin of the supplemental males is to be looked for in the occasional parthenogenetic development of eggs, but increases in the salinity of the nutrient medium, often considerable, effected no alteration in the sex proportions. It is well known that an increased osmotic pressure in the circumambient medium does often cause the parthenogenetic development of unfertilised eggs (*e.g.* Echinoderms and Annelids).

The free-living nematodes offer one of the best exceptions to the rule of cross-fertilisation among animals. The species under observation multiplied only by self-fertilisation for a year, but exhibited no signs of degeneration at the end of that period. Distinctly in contrast with this are such cases as *Ciona intestinalis*, where the eggs and spermatozoa of the same individual are said to be in general incapable of conjugation[1].

[1] Castle, "Early Embryology of *Ciona intestinalis*," *Bull. Mus. Comp. Zool.* XXVII. 1896.

Resolution of Optically active Ammonium Salts by means of Tartaric Acid. By H. O. Jones, M.A., Clare College.

[*Read* 25 November 1907.]

The first pure optically active ammonium compound was isolated by Pope and Peachey (*Trans. Chem. Soc.* 1899, lxxv. 1127), who then expressed the opinion that previous failures to resolve these compounds by means of tartaric and camphoric acids were due to hydrolysis: they therefore used strong acids and hydroxyl free solvents. That hydroxyl free solvents are unnecessary was shown (Thomas and Jones, *Trans. Chem. Soc.*, 1906, lxxxix. 280) when it was found that two brom-camphor-sulphonates were resolved on crystallising from water; and that a strong acid is not essential was shown by Miss Homer (*Proc. Camb. Phil. Soc.* 1907, xiv. 196) by resolving one of these asymmetric nitrogen compounds by means of tartaric acid.

Recently tartaric acid has been found extremely useful in resolving certain asymmetric nitrogen compounds which were not resolved or only resolved with great difficulty by the use of camphor-sulphonic and brom-camphor-sulphonic acids. The acid tartrates were found to be resolved on crystallising from alcohol.

This paper contains a preliminary account of the results in one particularly interesting case.

The second optically active nitrogen compounds to be prepared were the phenyl-methyl-ethyl-benzyl ammonium salts resolved by the writer (*Trans. Chem. Soc.* 1903, lxxxiii. 1419; 1904, lxxxv. 223) by fractional crystallisation of the dextro- and laevo-camphor-sulphonates from a warm mixture of ethylal and ethyl acetate. In this way the *d*-base *d*-acid salt was obtained having $[M]_D = +71°$ in aqueous solution, and the *l*-base *l*-acid salt with $[M]_D = -71{\cdot}2°$.

The molecular rotatory powers of the basic ions are therefore $+19{\cdot}3°$ and $-19{\cdot}6°$ respectively. The active iodides gave $[M]_D = \pm 30°$ in alcohol.

A similar result was obtained by Wedekind (*Ber.* 1904, xxxvii. 2727) using methyl formate as solvent.

Later, when examining a whole series of active ammonium salts to determine the effect of constitution on their rotatory powers, this salt was reexamined (Thomas and Jones, *loc. cit.* 286) with practically the same result.

It then became evident that this salt was quite out of place in the series since the value of $[M]_D$ for the corresponding *n*-propyl ion was 299° and for the isopropyl ion 398°.

It seemed extremely probable that the method used had not effected complete resolution, although the rotatory power of the salt was constant on recrystallisation. Attempts were therefore

made to apply other acids to the resolution of this salt, resulting in success with tartaric acid.

Meanwhile Wedekind (*Ber.* 1906, xxxix. 4437) had come to the conclusion that the camphor-sulphonate had only been partially resolved and had reinvestigated the question. The *d*-brom-camphor-sulphonate was prepared but could not be resolved. The *d*-camphor-sulphonate was then submitted to a long series of fractional precipitations from chloroform solution by the addition of ether. Large quantities of material were used which rapidly diminished as the process was repeated. After thirteen precipitations the value of $[M]_D$ for the salt was $+116°$; hence the basic ion has $[M]_D = 64°$, the iodide in alcohol gave $[M]_D = 138{\cdot}8°$ and 189° in chloroform. It is evident, however, that complete resolution in this way will be difficult.

The acid *d*-tartrate was made in aqueous solution by mixing molecular proportions in the ammonium hydroxide (prepared from the iodide by the action of moist silver oxide) and tartaric acid and evaporating nearly to dryness at 100° C. The salt is then obtained as a sticky mass which soon crystallises on standing, it is sparingly soluble in ordinary organic solvents, but much more soluble in water, from which it could be recrystallised easily; it is also easily recrystallised from hot rectified spirit.

Recrystallisation from water did not effect resolution, but recrystallisation from rectified spirit heated to about 60° C. soon gave a salt which was laevo-rotatory in aqueous solution and from which a laevo-rotatory iodide was precipitated. Finally, after about 20 recrystallisations the salt appeared to be completely resolved as its specific rotatory power in aqueous solution remained constant at about $-59°$.

The salt on analysis was found to have a composition corresponding to $C_6H_5 . CH_3 . C_2H_5 . C_7H_7 . NC_4H_5O_6 + 2H_2O$ and melted at 90° to 93° C.

The value of $[M]_D$ is therefore about $-240°$, taking the value of $[M]_D$ for the acid tartrate ion as $+42°$ we get the value of $[M]_D$ for the basic ion $= -282°$.

This is still lower than that of the corresponding *n*-propyl ion, 299°.

The iodide was easily recovered from the aqueous solution of the tartrate by the addition of sodium iodide solution. It melted at 149° to 150° C. and had $[M]_D = -312°$ in alcohol and $-385°$ in chloroform. In chloroform the iodide gradually became inactive as all these iodides do.

These results cannot yet be regarded as final, and the experiments are being repeated on larger quantities of the salt. The corresponding allyl compound has also been resolved by means of tartaric acid.

Studies on Platinocyanides. By L. A. Levy, B.A., Clare College.

[*Read* 25 November 1907.]

The majority of platinocyanides exhibit fluorescent properties. The best of these salts in this respect is barium platinocyanide, which exhibits a green fluorescence under the action of ultra-violet light, X rays, radium rays, etc. In the course of some experiments, a quantity of this salt was prepared by double decomposition between the copper salt and baryta. The crystals are golden yellow and dichroic showing a purple sheen. They often exhibit red and green colours on the edges, especially when immersed in water. The fluorescence exhibited by the salt under ultra-violet light or radium is very poor.

If this yellow salt be recrystallised from a solution to which very small amounts of certain substances have been added, a very marked difference is produced in the appearance of the salt and in the intensity of fluorescence which it exhibits. The experiments performed indicate that the properties of barium platinocyanide are greatly affected by crystallising from solution with traces of certain impurities. The salt which crystallises out is green instead of yellow and markedly fluorescent. The experiments performed indicate that the production of the *green* salt may be determined by the presence of:

(*a*) Potassium ions.
(*b*) Cyanogen ions.
(*c*) Hydroxyl ions.

(*a*) *Potassium ions.* This supposition, which appeared probable because many potassium salts were effective in producing the change, is disproved by the fact that barium cyanide and baryta are extremely efficient.

(*b*) *Cyanogen ions.* This hypothesis was suggested by the following facts:

(i) Substances yielding cyanogen ions have most effect.

(ii) Unionised cyanides, e.g. mercuric cyanide, cyanogen iodide, have no effect.

(iii) Substances yielding few cyanogen ions, e.g. potassium ferrocyanide and potassium thiocyanate, have a small effect.

(*c*) *Hydroxyl ions.* This hypothesis, which appears to be the most probable, is justified because

(i) Ionised cyanides produce large effects. All these are

more or less hydrolysed by water in a warm solution yielding HCN and $\dot{M} + O'H$.

(ii) Alkalies are efficient in producing the change.

It was found possible to reconvert the *green* salt, obtained as already described, to the *yellow* form by crystallising it out from a slightly acidified solution. It appears then that hydrogen ions may determine the deposition of the yellow form.

The differences between the green and yellow forms may be due to:

(*a*) A difference in chemical composition.

(*b*) A difference in the number of molecules of water of crystallisation.

(*c*) The formation of a thin film of double salt.

(*d*) A difference of crystalline habit.

(*e*) A difference of molecular weight.

(*f*) Isomorphous modifications of the same salt.

Difference in chemical composition. Brochot and Petit prepared barium platinocyanide by electrolysis of a solution of barium cyanide between platinum electrodes, using an alternating current. The salt obtained is described by them as yellow, slightly dichroic and very slightly fluorescent under radium. They say that this product becomes fluorescent if crystallised out with cyanides. They have analysed the two forms and state that they both have the same composition, although they give very few figures in support of their analyses.

The formation of a thin film of double salt is an unlikely explanation since the nature of the impurities effecting the change is very varied and different salts would be formed. There is no obvious reason why this should improve the fluorescence.

Differences due to crystalline habit.

Crystals of barium platinocyanide appear green along one axis and yellow along another axis. Possibly the two forms are due to a development along each of these axes.

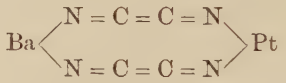
With a view to testing this hypothesis, experiments were made on the density and the crystalline characters of the two forms. The results obtained indicate that the density of the yellow form is rather less than that of the green modification, the mean values obtained respectively being 2·076 and 2·085 with respect to chloroform at 17° C.

Prof. Lewis has kindly measured the two varieties of the salts and furnished the following report.

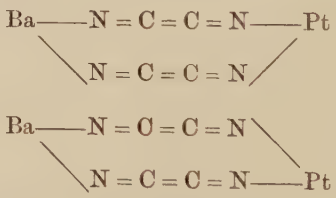
"The crystals of the two varieties of barium platinocyanide are identical crystallographically, and the angle of extinction in the plane of symmetry is in both cases very nearly in the direction of the longest edge which is selected in all descriptions as the vertical axis."

This report clearly shows that the differences cannot be determined by a difference of crystalline habit.

Having regard to all the evidence, the hypothesis of two modifications of the same salt appears to be the most likely. One structural formula which has been proposed for platinocyanides is derived from complex double molecules of hydrocyanic acid. Thus



In this formula the barium and platinum are similarly situated. It does not show that the barium is exclusively basic and the platinum exclusively acidic, so that they are quite uninterchangeable. A solid model shows that there is only one possibility of isomerism on this formula—a kind of oxime isomerism represented graphically as follows:



This is a possible explanation of the existence of the two forms —the deposition of one being determined by alkali, that of the other by acid; and the green form being the more stable.

My thanks are due to Dr Fenton for valuable advice.

The absorption spectra of collidine and 9-chlor-collidine. By J. E. Purvis, M.A., St John's College, and W. H. Foster, M.A., St John's College.

[*Read* 25 November 1907.]

Among the products of the action of chlorine on collidine, at present under investigation by Sell and Foster, there is one of special interest, in that it contains nine chlorine atoms in the molecule. The investigation by chemical methods appeared to show that these nine atoms of chlorine had replaced the hydrogen atoms in the three methyl groups of the collidine side chains; and it was thought that some additional information might be obtained from a spectroscopic examination of the absorption bands.

Moreover, the very considerable displacement of hydrogen by chlorine rendered the body a favourable subject for the study of the effect of loading the molecule on the spectrum. The introduction of nine chlorine atoms means the production of a molecule nearly four times as heavy as the original collidine, so that we could reasonably expect a considerable shift of the absorption band towards the red end of the spectrum. That this surmise was correct is proved in the following account of the spectroscopic examination of this body compared with that of collidine, neither of which has been studied previously.

The adjustable cell used to contain the solutions was not unlike that very useful instrument described by Baly and Desch (*Jour. Chem. Soc.*, vol. 85, pp. 1029—1041). Their cell consisted of two glass tubes with a quartz plate sealed on one end of each tube. The outer tube had a broad indiarubber band slipped over the junction between the outer and inner tubes to keep it water-tight.

But, in order to avoid the possible action of organic liquids on rubber, we had a long brass screw fitted on to the open end of the outer tube, and a washer or ring of cotton thread between the end of the screw and the screw head itself; so that, on screwing up the head, the cotton thread acted as an efficient plug, and thereby acted as a stopper to the leakage of any of the solution. Besides that, the position of the inner tube was made more rigid and firm.

The iron arc was used as the source of light to pass through the absorbing liquids. But it has some disadvantage caused by its irregularity and shifting, so that there is some difficulty in obtaining a light of regular intensity. In later experiments with other substances, we have used the iron spark as the source of light.

The absorption spectra of pyridine have been observed and described by Hartley (*Journ. Chem. Soc.*, vol. 47, pp. 685—757); and Baker and Baly, more recently, in their valuable researches, have examined the spectra again, and compared the curve obtained with that of lutidine, a dimethyl derivative of pyridine, and also with the curves of various chlorine derivatives of pyridine (*Journ. Chem. Soc.*, vols. 91 and 92, pp. 1122—1132).

The latter investigators showed that the effect of introducing two methyl groups into pyridine did not alter the character of the band, but moved it a little towards the red end of the spectrum, and also decreased its persistence. And, that, in the tri-, tetra-, and penta-chlorine derivatives of pyridine, the introduction of the chlorine atoms produced a gradual shift of the bands towards the red end, whilst the persistence was gradually increased.

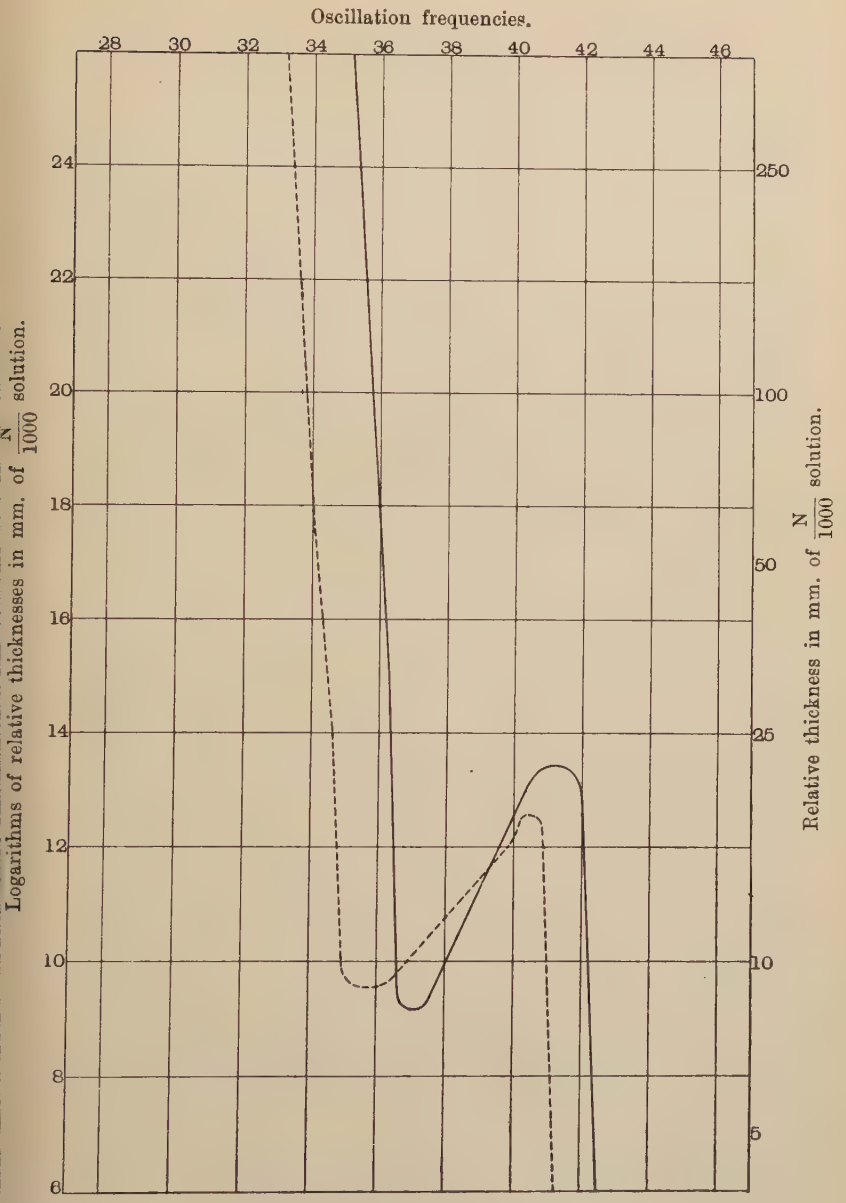
We have studied the absorption spectra of collidine and 9-chlor-collidine in a similar way; and, in order to compare the curves obtained with those of pyridine and its derivatives in Baker and Baly's experiments, we used equivalent strengths of $\frac{N}{1000}$ solutions in absolute alcohol, and plotted the results in the adjoining curve, so that the ordinates represent the logarithms of relative thicknesses, and the abscissæ represent oscillation frequencies.

As a result of this comparative study of the curves we find that the character of the collidine band does not appear to be different from that of pyridine or of lutidine, except that it is moved a little more towards the red end of the spectrum, whilst the persistence is decreased a little more than that of lutidine, and also, of course, more than that of pyridine. This result might have been expected because of the introduction of a third methyl group in the pyridine nucleus. The heads of the bands, expressed in oscillation frequencies, are the following:

Pyridine	3950	(Hartley)
Lutidine	3750	(Baker and Baly)
Collidine	3700	(Purvis and Foster).

With regard to the 9-chlor-collidine, the character of the band is again not essentially different from that of collidine; but there is a much greater shift towards the red end, and also a slight decrease in the persistence of the band.

Now, the persistence of the bands of the tri-, tetra-, and penta-chlorine derivatives of pyridine described by Baker and Baly, is so much greatly increased by the introduction of the chlorine atoms into the nucleus, that it appears to be very probable the nucleus has not been greatly affected, if at all, by the introduction of nine chlorine atoms in the collidine molecule.



Full curve; Collidine.
Dotted curve; 9-chlor-collidine.

It looks as if all the hydrogen atoms in the three methyl groups had been replaced by the chlorine atoms, and that none had entered the nucleus. For, if one or more of the chlorine atoms had been introduced into the nucleus, we should have expected that the persistence of the band would have been greatly increased; whereas the persistence is less than that of either collidine or lutidine or pyridine.

On the other hand it might be argued that if the weighting of the side chains tends to decrease the persistence of the band, as it does in collidine and lutidine when compared with that of pyridine, we might have expected that there would have been a more marked decrease in the persistence of the band of the 9-chlor-collidine, if the chlorine atoms had replaced the hydrogen atoms of the side chains.

Further, assuming that one or more of the chlorine atoms are in the nucleus, their influence would be to increase the persistence of the band; whilst the influence of the other chlorine atoms in the side chains would be to decrease the persistence, and the net result would be a balancing of two influences acting in opposite directions.

Nevertheless, the explanation that the chlorine atoms had replaced the hydrogen atoms of the three methyl groups agrees better so far with the chemical results of the investigation.

The shift of the 9-chlor-collidine band towards the red end can be compared with the shifts of the bands of the chlorine derivatives of pyridine; the heads of the bands are expressed in oscillation frequencies:

Tri-chlor-pyridine	3650	(Baker and Baly)
Tetra-chlor-pyridine	3500	(do.)
Penta-chlor-pyridine	3400	(do.)
9-chlor-collidine	3580	(Purvis and Foster).

These numbers show that the shift of the band of the collidine derivative is less than the shifts of the tetra- and penta-chlor-pyridines, but greater than that of the tri-chlor-pyridine.

The great shift of the absorption band of the 9-chlor-collidine towards the red end of the spectrum agrees with the general effect observed by Hartley as regards substituted compounds; that there is a greater shift of the absorption band towards the red end, the higher the weight of the group introduced into the molecule.

We are continuing the study of other chlorine derivatives of these substances.

The Action of metallic Magnesium on certain aliphatic acids, and the detection of Formic acid. By H. J. H. Fenton, Sc.D., F.R.S., Christ's College, and H. A. Sisson, B.A., Clare College.

[*Read* 25 November 1907.]

In a previous communication (*Trans. Chem. Soc.* 1907, 687) it was shewn that both carbonic and formic acids may be reduced to formaldehyde by means of metallic magnesium. Experiments have since been undertaken with the object of ascertaining whether an analogous reduction can be effected in other acids; the results, as far as they go, appear to indicate that such a reduction only occurs in the lower members of a series. With formic acid the reduction is easily recognisable even in very dilute solutions, but in the cases of acetic, propionic and butyric acids the formation of aldehydes is only apparent when strong solutions are employed and the temperature is allowed to rise. Oxalic acid yields, even in cold dilute solutions, notable quantities of an aldehydic product which presumably is glyoxylic acid. Negative results were obtained with malonic, succinic, glycollic, lactic, tartronic, tartaric, malic and many other acids.

The reduction by means of metallic magnesium may be employed as a specific test for formic acid; the usual methods of detecting formic acid depend, for the most part, only upon its reducing properties, whereas the reactions of formaldehyde are of a far more positive character.

The solution to be examined is digested with the metal, in the form of ribbon or powder, at the ordinary temperature for some minutes, and the resulting product is tested for formaldehyde by any of the usual colour tests or, if the quantity is sufficient, by means of phenylhydrazine. Soluble metallic formates give a similar result, but the reaction is much more delicate when the free acid is employed.

Some colour-reactions of organic acids with Phenols. By H. J. H. Fenton, Sc.D., F.R.S., Christ's College, and G. Barr, B.A., Christ's College.

[*Read* 25 November, 1907.]

It is well known that certain organic acids give rise to remarkably brilliant colour-reactions when they are acted upon by phenolic compounds in presence of dehydrating agents. With the object of ascertaining to what extent these reactions might be applicable to the preliminary identification of acids, the authors have tabulated the results obtained when a few of the less common acids are treated with phenols, at the ordinary temperature, in presence of strong sulphuric acid. By comparing the colours obtained in this way with two or more phenols, information of a positive character may often be obtained. The method has the advantage of being applicable not only to the acids but also to their salts or esters, and it may be employed for provisional identification when only minute quantities of the substance are available.

The following table shews the results of preliminary observations made in a rough qualitative manner. In a few cases the effects are modified if considerable excess of one or other reagent is employed. When dry metallic salts are used it is sometimes necessary to add a drop of water to the mixture in order to obtain the characteristic colour mentioned.

Formic	Strong orange-red, changing later to blood-red Ammonia added to diluted solution gives green passing to purple	Pink solution	Pink solution, changing to orange-red and nearly scarlet	Light red
Oxalic	Slight yellow, becoming dark blue after standing some time: changed by ammonia to pink colour	Slight pink, red on standing	Light yellow, passing slowly to blue	Crimson (slowly)
Dioxytartaric	Orange, changing quickly to dark prussian blue: changed by ammonia to red colour	Faint yellow, passing to reddish-brown: changed by alkalis to transient blue	Dirty green, becoming orange Ammonia, intense blue passing to purplish brown	Crimson at once Ammonia gives purple
Pyruvic	Orange-brown	Orange, becoming pink on exposure to moisture	Orange-brown, changed by ammonia to violet	Orange to pink
aa-Dimethyl-glutaric	Intense blue, changed by water to red-violet Alkalis restore blue	Light yellow, passing to emerald green	Brownish solution	Negative
Lactic	Yellow passing to orange Ammonia yields highly fluorescent solution (green)	Yellow or orange	Orange	Red-brown
Saccharic	Intense blue, changed by ammonia to green	Yellow, changed by ammonia to green	Intense red-brown	Intense green
Laevulinic	Orange-brown to crimson, changed by ammonia to intense, transient yellow	Orange-brown	Intense red	Slight brown
Oxalacetic	Intense orange	Yellow	Intense orange	Negative

The following acids gave insignificant or negative results:

Acetic, butyric, stearic, mono- di- and tri-chloracetic, aminoacetic, glycollic, malonic, succinic, suberic, sebacic, tartaric, citric, malic, mucic, dihydroxymaleic, fumaric, maleic, itaconic, tartronic, acetylene dicarboxylic, citrazinic, hippuric, cyanuric, dibromosuccinic, cinnamic, mesitylenic, *1* phenyl *3* pyrazolon carboxylic. Fluorescent solutions are obtained from the products with resorcinol and the following acids or esters: acetoacetic, dicarboxyglutaconic, β hydroxybutyric, phthalic, and, on adding ammonia to the product, hydrocyanic.

An example of complex double integration. By A. C. Dixon, Sc.D., F.R.S., Trinity College.

[*Received* 15 December 1907.]

Let U, V, W be rational integral algebraic functions of x, y of degrees m, n, $m+n-3$ respectively; then it is a known result, given by Jacobi, that $\Sigma W \Big/ \frac{\partial(U, V)}{\partial(x, y)} = 0$, where the summation extends to all pairs of values of x, y, such that $U = V = 0$: it is assumed that these pairs are all distinct. If homogeneous coordinates x, y, z are used the corresponding theorem is that $\Sigma z W \Big/ \frac{\partial(U, V)}{\partial(x, y)} = 0$, and in this form it is unaffected by a change of the triangle of reference, which may therefore be supposed to have a quite general position. The object of the present note is to prove this theorem by double contour integration.

Suppose that the line $z = 0$ does not contain any intersection of the curves $U = 0$, $V = 0$ or any singular point on either, and that the values $x = 0$, $z = 0$ do not satisfy either equation. Put $z = 1$.

When x has any given value the equation $U = 0$ gives m values for y, say $y_1, y_2, \dots y_m$ and $V = 0$ gives n, say $\eta_1, \eta_2, \dots \eta_n$. When x is made great the ratios y_1/x, $y_2/x \dots$, η_1/x, $\eta_2/x \dots$ tend to definite limits which are all different, and we may therefore take a radius r, such that when $|x| > r$, every difference such as $y_s - \eta_t$ is numerically greater than $e|x|$, where e is a definite constant, depending to some extent on the coefficients in U, V.

Let the complex variable x describe a circle of radius $R\ (> r)$ about the origin in its plane. Then in the y plane the points $y_1, y_2 \dots, \eta_1, \eta_2 \dots$ will also travel about but will not approach each other, and in fact if a circle of radius $\frac{1}{3}eR$ is described about each of them these circles will always be separate. Take for y a path enclosing the circles about $\eta_1, \eta_2 \dots \eta_n$ and excluding those about $y_1, y_2 \dots y_m$. The length of this path may be supposed $< kR$ where k is a finite quantity.

Let us estimate the value of $\iint \frac{W}{UV}\, dy dx$ over the region thus defined, which is closed, since the initial and final positions of the point x and of the y-path, which is closed, are the same.

We have $U = a(y - y_1)(y - y_2) \dots (y - y_m)$, where a is the coefficient of y^m, and thus on the path $|U| \nless |a|(\frac{1}{3}eR)^m$, since each difference, such as $y - y_r$, never falls below $\frac{1}{3}eR$. Similarly, on the path $|V| \nless |b|(\frac{1}{3}eR)^n$ where b is the coefficient of y^n in V. Hence, W being of degree $m + n - 3$, we have, on the path,

$$|W/UV| \ngtr c/R^3 \text{ where } c \text{ is a constant.}$$

Now the lengths of the x-path and y-path are respectively $2\pi R$ and $\nmid kR$, so that the integral does not numerically exceed

$$2\pi R \,.\, kR \,.\, c/R^3 \text{ or } 2\pi ck/R,$$

and therefore tends to zero as R increases.

An expression for the value of the integral can also be found as follows. In the first integration, with respect to y, the subject is uniform and has poles $\eta_1, \eta_2 \ldots$ enclosed by the path. Hence the result of the first integration is

$$2\iota\pi \sum_{r=1}^{n} \left\{ W/U \frac{\partial V}{\partial y} \right\}_{y=\eta_r}.$$

This expression is symmetrical in $\eta_1, \eta_2 \ldots \eta_n$, and is therefore a rational function of x which may become infinite through the vanishing either of U or of $\partial V/\partial y$, when $y = \eta_1, \eta_2 \ldots$.

When $\partial V/\partial y = 0$ we have either a branch-point of the functions $\eta_1, \eta_2 \ldots$ or a node on the curve $V = 0$; the latter cannot make U vanish also, by hypothesis, and we may if necessary change the axes so that U does not vanish at any of the branch-points. We shall in fact choose for axis of y a line that is not parallel to the tangent to $V = 0$ at any point where it meets $U = 0$ or to any line that contains two of the intersections of $U = 0$, $V = 0$.

Suppose first then that $\partial V/\partial y = 0$, when $x = x_1$, $y = \eta_1$, and therefore $U \neq 0$. Two or more terms in the summation are infinite, but their sum is finite as will now be shewn. Suppose to fix the ideas that η_2 comes into coincidence with η_1 when $x = x_1$. Then before integrating at all we may deform the field and make the x-path exclude x_1. The form of the y-path must of course vary with x so as always to include $\eta_1, \eta_2 \ldots$ and exclude $y_1, y_2 \ldots$, but this is not made more difficult by a coincidence between η_1, η_2 which are both included. The conclusion is then that we may suppose all such points excluded from the x-path, and that we are only concerned with values of x such that U, V vanish together for some value of y. It is easy to calculate the residue in such a case, for only one term in the series $\Sigma W \Big/ U \frac{\partial V}{\partial y}$ becomes infinite, by supposition, and its residue is

$$W \Big/ \frac{\partial U}{\partial x} \frac{\partial V}{\partial y},$$

where $\frac{\partial U}{\partial x}$ is formed on the understanding that y is a function of x given by $V = 0$. The residue is therefore

$$W \Big/ \frac{\partial (U, V)}{\partial (x, y)},$$

and the double integral $= (2\iota\pi)^2 \Sigma W \Big/ \frac{\partial(U, V)}{\partial(x, y)}$, the summation being over all the solutions of the equations $U = 0 = V$. Since the double integral tends to zero as R increases, Jacobi's theorem follows.

The corresponding theorem for a single variable is of course that $\Sigma g(x)/f'(x) = 0$ if $g(x)$, $f(x)$ are of degrees $n-2$, n and the summation extends over all the roots of $f(x) = 0$. If $g(x)$ is of higher degree it may be put in the form

$$\phi(x) f(x) + cf'(x) + g_1(x),$$

where c is constant and $g_1(x)$ of degree $n-2$ at most. Then we have $\Sigma g(x)/f'(x) = nc$. There is a similar extension with two variables, depending on the following lemma:—

If W is of degree r, higher than $m+n-3$, we can find a constant c and quantics A, B, Z in x, y, 1 of degrees $r-m$, $r-n$, $m+n-3$ such that $W = AU + BV + cJ + Z$ where

$$J = \partial(U, V)/\partial(x, y).$$

Assuming this we have

$$\Sigma W/J = \Sigma (AU + BV + cJ + Z)/J,$$

where U, V vanish in each term and $\Sigma Z/J = 0$. Since there are mn terms $\Sigma W/J = mnc$.

To prove the lemma, let u, v, w, j denote the terms of highest degree in U, V, W, J and take first the case $r = m+n-1$. Then we can choose binary quantics ϕ, ψ in x, y of degrees $n-1$, $m-1$ such that

$$u\phi + v\psi = w;$$

for we have here, in fact, $m+n$ linear equations to find the n coefficients of ϕ and the m coefficients of ψ, and the determinant of the left sides of these equations is the eliminant of u, v, which by hypothesis does not vanish. Hence ϕ, ψ are determinate and are such that $W - U\phi - V\psi$ is of degree $m+n-2$ only.

If W is of higher degree, r, we can put (not uniquely)

$$w = \alpha f + \beta g + \ldots,$$

where f, g ... are quantics of degree $m+n-1$, α, β ... quantics of degree $r-m-n+1$, and apply the same method to f, g ...; thus ϕ, ψ may again be found, but not uniquely, so that $w = u\phi + v\psi$ and the degree of $W - U\phi - V\psi$ is $r-1$ only.

In this way by successive steps A_1, B_1 may be found so that $W - A_1 U - B_1 V$ is of degree $m+n-2$ only, and we have now only to discuss the case $r = m+n-2$.

Since here xw is of degree $m+n-1$, we have

$$xw = u\phi + v\psi,$$

and there being no term on the left without x, the coefficients of y^{n-1} in ϕ and y^{m-1} in ψ must be as b to $-a$; suppose that they are $bcmn$ and $-acmn$. Then

$$\phi - cm\,\partial v/\partial y \text{ and } \psi + cn\,\partial u/\partial y$$

contain the factor x; suppose the other factors to be χ, ω. Thus

$$\begin{aligned} xw &= u\left(x\chi + cm\frac{\partial v}{\partial y}\right) + v\left(x\omega - cn\frac{\partial u}{\partial y}\right) \\ &= x(u\chi + v\omega + cj), \end{aligned}$$

and $W - U\chi - V\omega - cJ$ is of degree $m+n-3$ at most, so that the lemma is proved.

The special case when $W = J$ is worthy of notice: the number (mn) of solutions of $U = 0 = V$ is given as $\frac{1}{(2\iota\pi)^2}\iint \frac{J}{UV}\,dy\,dx$* over the field specified. To verify this we note that since J is of degree $m+n-2$, the integral need not tend to zero as R increases but that only the terms of the highest degree in U, V, J will influence the result. The result will then not be affected if we substitute for U, V products of linear factors, so long as the highest terms in U, V are unchanged. Thus we may take

$$U = a\prod_{r=1}^{m}(y - y_r) \text{ where } y_r = l_r x + f_r,$$

$$V = b\prod_{r=1}^{n}(y - \eta_r) \text{ where } \eta_r = g_r x + h_r.$$

Then it is not hard to prove that

$$J/UV = \sum_{r=1}^{m}\sum_{s=1}^{n}(g_s - l_r)/(y - y_r)(y - \eta_s),$$

(see *Camb. Phil. Proc.* Vol. XII. pt. 6, p. 30). Each of these mn fractions contributes $(2\iota\pi)^2$ to the integral, so that the result follows.

* It is stated by Picard and Simart that this integral, which was studied by Didon, does not give the number of common zeros of the factors of the denominator enclosed by the field of integration. (*Fonctions algébriques de deux variables indépendantes*, vol. I. ch. 3.)

On a new genus of Ixodoidea together with a description of eleven new species of ticks. By George H. F. Nuttall, Sc.D., F.R.S., Christ's College, Quick Professor of Biology, and Cecil Warburton, M.A., Christ's College, Zoologist to the Royal Agricultural Society.

[*Received* 28 December, 1907.]

In the course of the last few years we have received numerous specimens of ticks collected in various parts of the world. The majority belong to well-known species. In view of the frequently inadequate descriptions in the literature relating to ticks a number of specimens have not as yet been definitely classed. On the other hand we have encountered eleven undescribed species, one of which forms the type of a new genus (*Rhipicentor*):

List of New Species.

1. *Ixodes cavipalpus* (♂ and ♀).
2. „ *kelloggi* (♀).
3. *Haemaphysalis wellingtoni* (♂ and ♀).
4. *Rhipicentor bicornis* (♂ and ♀).
5. *Rhipicephalus coriaceus* (♂ and ♀).
6. *Rhipicephalus masseyi* (♂ and ♀).
7. *Amblyomma versicolor* (♂ and ♀).
8. „ *atrogenatum* (♂).
9. „ *cooperi* (♂ and ♀).
10. „ *uncatum* (♂).
11. *Hyalomma monstrosum* (♂).

For the sake of brevity and precision we have adopted certain signs and terms in our description, these being explained in the following table.

Explanation of terms and signs used in the following diagnoses.

L. = the extreme length of the tick excluding the capitulum and legs.
W. = its width at the widest part.
(*l.* and *w.* refer to length and width of various structures.)
Dorsum = the whole dorsal surface of the body.
scutum = the "dorsal shield," "Kopfschild," etc. of some authors. (Size stated by giving the length first, then the greatest width (including the eyes if protruding), thus ·9 × ·7 mm.)
pseudoscutum = that portion of the male scutum which corresponds in shape and position with the female scutum, and is sometimes outlined by a ridge, punctations or hairs, without being a definite structure.
emarginate means hollowed out for the reception of the capitulum.

scapulae=the anterior angles or "shoulders" of the scutum projecting on either side of the emargination and included in measurements of the length.

cervical grooves=the term commonly applied to the pair of grooves running backward from the inner angles of the scapulae.

lateral grooves=grooves running along the sides of the scutum in both sexes; they are spoken of as "complete" if they are continuous along the anterior border of the festoons.

marginal grooves=grooves running along the sides of the body in the female.

foveolae=the "submedian dorsal porose areas" of Salmon & Stiles, two small spots often observable near the middle of the scutum in the male, posterior to the scutum in the female.

VENTER=the whole ventral surface of the body.

spiracle=the "peritreme" or "stigmal plate" of some authors; we refer to the *macula* instead of to a "pore" in its centre.

vulva=the genital orifice of the female.

The nomenclature employed for the other structures appearing on the venter: grooves, shields, anal ring, anus, etc., are those usually employed.

plagues=chitinous patches on venter near festoons (see Fig. 30 *B*).

CAPITULUM=the "rostrum," "head" or "false head" of various authors.

basis capituli or shortly *base*=the basal ring, etc., of most authors. It often shows a transverse elevated *ridge* dorsally with edge directed backward. The ridge may have protruding angles, the latter we term *cornua*. There may also be a ridge ventrally. When the length of the capitulum is given it is measured from the tip of the hypostome to the *dorsal ridge* in the median line. Where the dorsal ridge is absent it is similarly measured to the *ventral ridge*. When the measurement is made ventrally this is stated, the dorsal measurement being usually employed. The clear space between the porose areas of the ♀ capitulum is spoken of as the *interval*.

hypostome=the "maxilla," "radula," "labium," or "Unterkiefer" of various authors. The dentition is indicated by figures on either side of a vertical line. Thus 3|3 means three longitudinal files of teeth on each half of the hypostome.

chelicerae=the "mandibles" or "pseudo-chelicerae" of some authors. The terminology usually applied to the portions of the *digit* of the chelicerae appears to us wrong and confusing, and we prefer to recognize (1) an "internal article," the latter bearing a "dorsal process" which is a portion of it (not articulated), and (2) an "external article" which articulates with the internal article upon its outer side.

internal article="median apophysis" or "immovable finger" of some authors.

dorsal process="internal apophysis" of some authors.

external article="external apophysis" or "free" or "movable finger" of some authors.

LEGS.—We adopt the usual terminology for the parts of the leg: coxa, trochanter, etc., ending with the tarsi. All processes on the articles of the legs are termed *spurs*. We have not referred to the structure of the claws and pulvillum in our descriptions.

N.B.—We do not consider further measurements than those mentioned above to be necessary in practice: viz. lengths of first article of chelicerae (an internal structure), hypostome, palps, legs, eyes, etc.; but we have usually

given in a footnote some measurements relating to the digit, spiracle, etc. We have thought it advisable to note any differences of coloration observable in the specimens when dry or when immersed in alcohol.

The figures are in most instances reduced from drawings made with the aid of the camera lucida from specimens mounted in balsam, any errors of interpretation due to the transparency of the chitin being corrected by reference to the opaque object. The digits are all of the right side, viewed dorsally, the spiracles appear as viewed from the left side, the tick being held horizontally (when gorged) or rotated on its long axis sufficiently to bring all parts of the spiracle into focus.

Ixodes cavipalpus n. sp.

Figures 1—5.

Male, L. 1·9, W. 1·2 mm. *Body* long oval (Fig. 1). *Scutum* accurately long oval, broadest in the middle, glossy, hairless, not covering the whole dorsum but leaving a marginal fold which is very narrow in front and gradually broadens posteriorly; no lateral grooves; cervical grooves* and punctations very faint. *Venter* brown with long hairs; sexual orifice between coxae III; pregenital plate longer than broad, narrow in front; anal grooves slightly divergent; adanal plates slightly broader in front; spiracles oval, white. *Capitulum* (Fig. 2) short (·5 mm.) like that of *Ix. ricinus* in general appearance; basis capituli with median posterior point ventrally; hypostome with six well-marked transverse ridges of teeth giving the effect of dentition 3|3. *Legs* moderately strong; coxa I with a slight spur, coxae II—IV unarmed; tarsi tapering gradually.

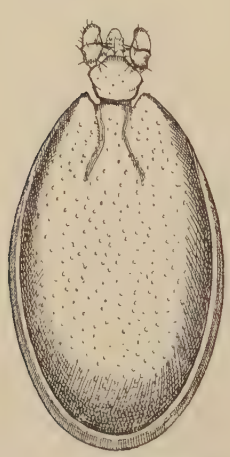


Fig. 1. ♂ dorsal aspect.

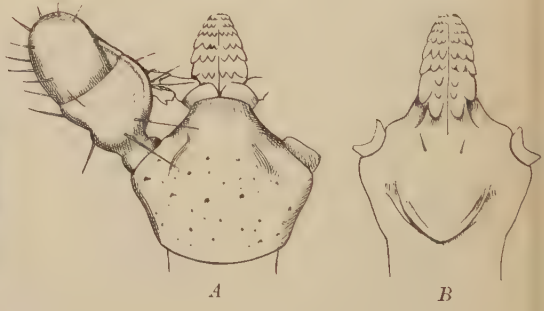


Fig. 2. ♂ capitulum, *A* dorsal and *B* ventral aspects. (The teeth on the hypostome in *A* are visible by transparency.)

* Accentuated in Fig. 1.

Female (more or less fed), L. 2·9 to 5, W. 1·8 to 3·3 mm. *Body* brown, with a few scattered hairs. *Scutum* (*l.* 1·3 to 1·4, *w.* 1 to 1·2 mm.) dark brown, long oval with slightly sinuous posterior border; cervical grooves shallow, almost reaching the

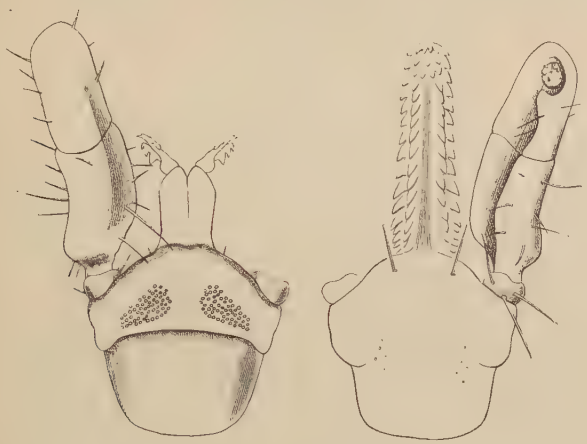


Fig. 3. ♀ capitulum, *A* dorsal and *B* ventral aspects.

margin; no lateral grooves; numerous fine shallow punctations. *Venter* brown, with scattered hairs, long at the sides; vulva between coxae IV; anal grooves nearly reaching the posterior border and slightly divergent; spiracles round, whitish. *Capitulum* (Fig. 3) fairly long (·9 mm.), base triangular with sub-triangular porose areas far apart; palps with article 2 concave outside (whence "cavipalpus") owing to lateral prominence proximally; hypostome long and narrow with a crown of small teeth followed by dentition 2|2. *Legs* as in ♂, but coxae I—II close together, III distant from II, and IV more distant from III; coxa I pointed, II—IV with straight posterior borders.

Origin. Description based on 2 ♂ and 7 ♀ from a baboon (*Cynocephalus babuin*), Kansanshi, N.W. Rhodesia, collected by Dr A. Yale Massey.

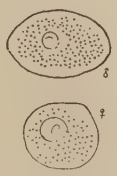


Fig. 4. ♂ and ♀ spiracles, respectively 370 μ and 270 μ *l.*

Fig. 5. ♂ and ♀ digits, respectively 138 μ and 140 μ *l.*

Note.—♂ *Digit* (Fig. 5) 138 μ long, internal article with triangular apex and point protruding outward, dorsal process large, extending midway along the article and ending in two teeth, external article bidentate. ♀ *Digit* (Fig. 5) 140 μ long, internal article slender, notched distally, dorsal process small, external article with large basal tooth, two smaller teeth anterior to it and fine denticles distally. *Spiracles* of ♂ 370 μ, ♀ 270 μ long (Fig. 4).

Near *T. pilosus*: differs in ♂ anal groove and absence of ♀ lateral groove.

Ixodes kelloggi n. sp.

Figures 6—8.

Male, unknown.

Female (fully fed), L. 7, W. 5·2 mm. *Body* brown, with numerous white hairs. *Scutum* (Fig. 6) very long, 1·4 × 1·0 mm., somewhat diamond-shaped, with a few conspicuous white hairs; scapular angles sharp, no lateral grooves; cervical grooves well-marked but not deep, slightly converging at first, then diverging to reach the margin nearly half-way along its postero-lateral border; several large shallow punctations, in part confluent, from some of which hairs have fallen. *Venter* with numerous white hairs; spiracles slightly oval, brown, macula central; vulva between coxa III; anal groove with parallel sides, rather short, terminating far from the posterior border. *Capitulum* (Figs. 6, 7)

Fig. 6. ♀ capitulum and scutum. × 20.

of medium length (·8 mm.); base triangular, cornua slight; porose areas large, transverse, of indefinite form; palps rather long and narrow, article 2 the longest; hypostome pointed, 3|3. *Legs* (Fig. 8) medium, coxa I with two spurs wide apart, coxae II—IV with short rounded outer spurs and inner edge blade-like; tarsi tapering.

Origin. Description based on 3 ♀, one from a thrush (from Palo Alto, Cal. 1895), one from *Cyancitta stelleri frontalis* (R. C.

Snodgrass, coll. 1895, California), and a third from a bird (probably California), sent by Prof. V. L. Kellogg of Stanford University in 1907. (In alcohol.)

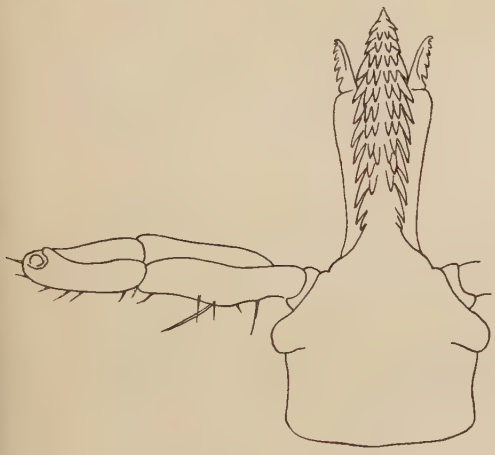


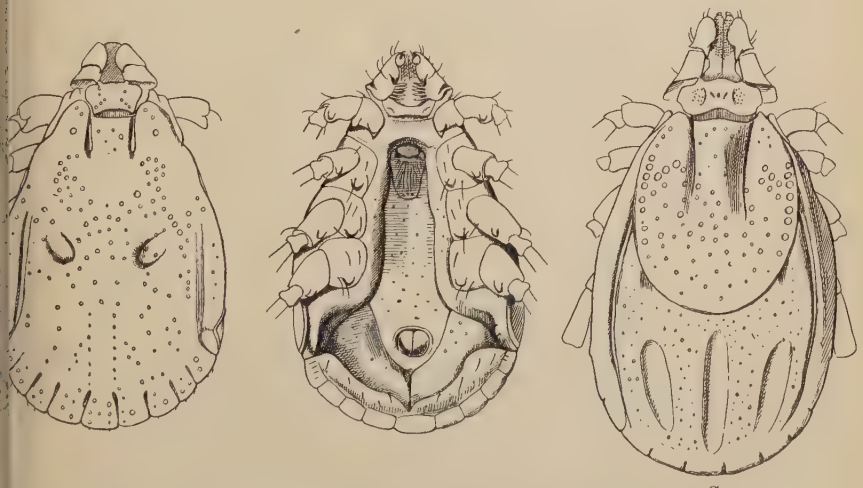
Fig. 7. ♀ capitulum, ventral aspect. ×70.

Fig. 8. ♀ coxae I—IV.

Haemaphysalis wellingtoni n. sp.

Figures 9—11.

Male, L. 1·3, W. 1 mm. *Body* (Fig. 9 *A* and *B*) oval, narrow in front, dark brown. *Scutum* glossy, with many medium-sized



A *B* *C*

Fig. 9. *A* ♂ dorsum, *B* ♂ venter, *C* ♀ dorsum.

punctations, especially posteriorly on the pseudoscutum; a non-punctate depression on either side of the centre; cervical grooves, deep, straight, parallel; lateral grooves short, including first festoon. *Venter* brown; spiracles white, bluntly piriform. *Capitulum* proportionately large (·3 mm. *l.*), base finely punctate, cornua slight; palps: article 2 projecting strongly laterally, article 3 with dorsal and ventral retrograde processes at inner angle; the outer borders of articles 2 and 3 form an unbroken line; hypostome broad, dentition 4|4. *Legs* brown, coxae strong, with a single short spur on each, strongest on coxa I.

Female (unfed), L. 1·5, W. 1·1 mm. *Body* (Fig. 9 *C*) brown, punctate, marginal grooves well marked. *Scutum* elliptical (·9 × ·7 mm.) sides nearly parallel, many rather large punctations, some confluent; cervical grooves long, nearly parallel, middle field broad, no lateral grooves. *Venter* brown; spiracles white, rounded. *Capitulum* proportionately very large (·6 mm. *l.*) with characteristics of ♂ (hypostome, Fig. 10); porose areas large, oval, far apart. *Legs* paler than body, coxae as in ♂.

Fig. 10. ♀ hypostome, 250 μ *l.*

Fig. 11. ♀ digit, 100 μ *l.*

Origin. Description based on 1 ♂ and 2 ♀ from fowl, Sarawak, Borneo, collected by Dr A. R. Wellington, 1907. (Preserved in spirit.)

Note.—♀ *Digit* (Fig. 11) 100 μ long, with dorsal process somewhat heart-shaped, protruding outwardly in the form of two rounded teeth, external article 4-toothed, the two distal teeth small.

Rhipicentor n. gen. Nuttall & Warburton, 1908.

Characters of Genus. ♂ resembles *Rhipicephalus* dorsally, *Dermacentor* ventrally. Basis capituli hexagonal with very prominent lateral angles. Coxa I strongly bifid and overlapping coxa II in ♂ and ♀; ♂ coxae progressively increasing in size to pair IV which is much the largest, pairs II—IV bifid. Adanal shields absent. Eyes present*.

* The description of the generic characters is based upon the examination of two species: *Rhipicentor bicornis* and a second species which will be described by our colleagues, Messrs W. F. Cooper and L. Robinson.

Rhipicentor bicornis n. sp.

Figures 12—16.

Male, L. 5·1, W. 3·1 to 3·2 mm. *Body* (Figs. 12 and 13 *A*) brown, long oval, somewhat pear-shaped. *Scutum* covers the whole dorsum, deeply emarginate, glossy, with few punctations, these chiefly in front and on the lateral folds; cervical grooves short, deep, linear, converging; lateral grooves well marked, beginning

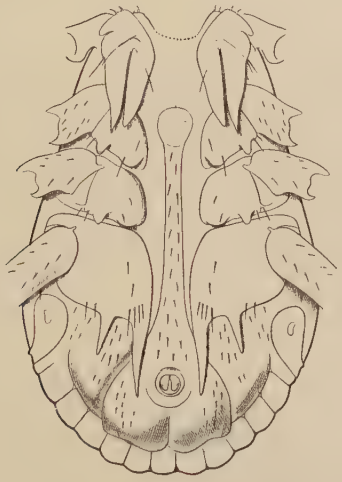
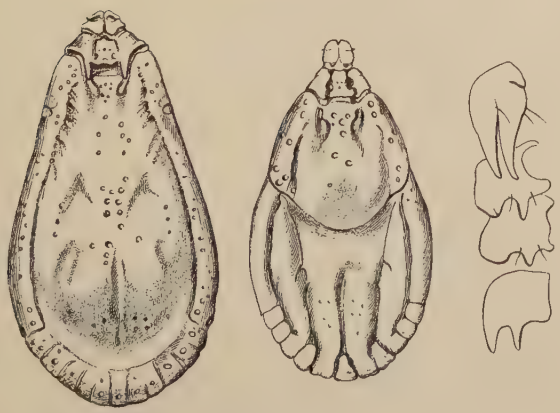


Fig. 12. ♂ venter, *l.* 5·75 mm.



A *B* *C*

Fig. 13. *A* ♂ dorsum, *B* ♀ dorsum, *C* ♀ coxae I—IV.

at the level of the cervical grooves in the form of confluent punctations and rugosities and terminating in front of the outermost festoons; no clearly marked grooves on the posterior part of the scutum; eyes small, round, red brown, marginal. *Venter*: spiracles (Fig. 16) long comma-shaped; genital grooves parallel. *Capitulum* (Fig. 14) (·9 to 1·0 mm. long (ventral)) with very large

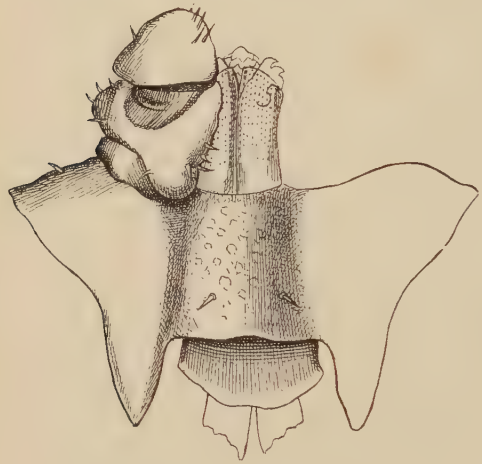


Fig. 15. ♂ digit, 165 μ *l.*

Fig. 14. ♂ capitulum, dorsal and ventral aspects.

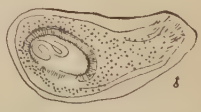


Fig. 16. ♂ spiracle, ·9 mm. *l.*

hexagonal base, the lateral angles sharply projecting, the cornua long and strong (whence "bicornis"), the median area covered by confluent punctations; palps very short and broad; article 1 has

a strong retrograde ventral tooth, and an inwardly-directed flange-like process difficult to see *in situ* and bearing hairs on its margin (see Fig. 14); a slight ventral retrograde process on article 3; hypostome 3|3, rather spatulate. *Legs* strong; coxa I with two strong spurs, near together, projecting well over coxa II, also a third anterior spur directed over the trochanter; coxae II and III with a conical outer spur and a blade-like inner spur; coxa IV, which is much the largest, with two strong spurs rather near together and somewhat diverging, the inner reaching to the anus, the outer about half as long (Fig. 12); a dorsal spur on trochanter I. Other articles as in *Dermacentor*. Numerous strong short spines on all the articles.

Female (unfed), L. 4·2, W. 2·6 mm. (Fig. 13 *B*). *Scutum* about as long as broad (2·1 × 2·3 mm.), with few punctations as in ♂; posterior border sinuous; eyes obscure, slightly anterior to the lateral angles; cervical grooves of moderate length; lateral grooves parallel, the sides of the scutum being very prominent and darker in colour; marginal grooves extending backward to include the two extreme festoons. *Venter*: spiracles short comma-shaped (as in *A. versicolor*, Fig. 29 ♀). *Capitulum* (1·1 mm. *l.*) base less protuberant laterally than in ♂ and with only slight cornua; palps much longer than in ♂ and with rounded lateral contour. *Legs* (Fig. 13 *C*) long and strong; the coxae do not differ greatly in size and they are spurred as in ♂ except that the spurs on coxae II—III are *longer* while the spurs on coxa IV are sub-equal and short.

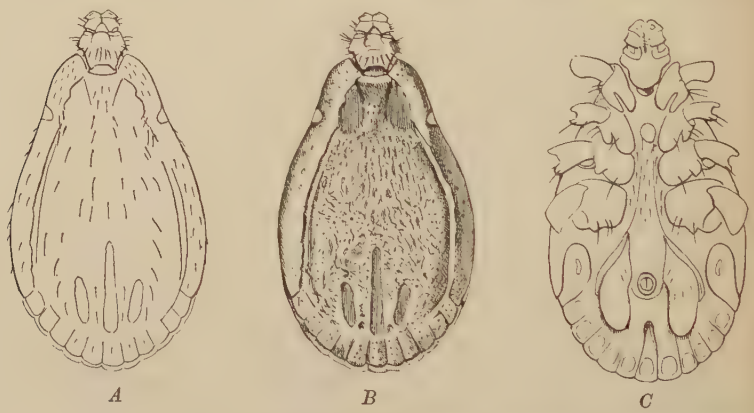
Origin. Description based on 3 ♂ and 1 ♀ collected by Dr Old in North Nyassa, British Central Africa. Host not stated (preserved in 5 % formalin, then in spirit). We have also received a fully gorged ♀ collected by Dr A. Yale Massey at Kansanshi, N.W. Rhodesia, which was found in a dwelling. It agrees almost precisely with our ♀, its scutum measures 2·3 × 2·6 mm., but the legs are much stouter. It is a large specimen: L. 16·9, W. 14 mm. Notwithstanding its gorged condition the festoons are still well-marked.

Note.—The *Digit* (Fig. 15) of ♂ 165 μ long, short and thick with dorsal process very stout, transverse, bidentate externally; external article with small distal tooth followed by a large tooth. The *foveolae* of ♂ small, 80 μ across, round, the interval between them 170 μ (see Fig. 13 *A* where they lie posterior to a central group of punctations of about the same size).

Rhipicephalus coriaceus n. sp.

Figures 17—20.

Male, L. 4·3, W. 2·9 mm. to L. 4·5, W. 3·0 mm. *Body* (Figs. 17 *A*, *B* and *C*) narrow in front, impressed at the level of the eyes. *Scutum* covers the whole dorsum, red brown on the scapulae, very dark brown elsewhere, very coriaceus (whence the name) with rugosities rather than punctations; cervical grooves convergent behind, their outer limits undefined, merging into a broad, flat, dull, depressed area bounded by a ridge which continues the lateral groove anteriorly; marginal groove well-marked to the first festoon, continued more faintly to the second festoon; numerous white hairs especially outside the marginal grooves, and around the border of the pseudoscutum, the others forming longitudinal rows; posterior depressions somewhat linear; eyes flat, pale. *Venter* yellow, hairy; genital grooves nearly parallel; adanal shields large, dark brown, hairy, the outer side convex, bluntly pointed behind; the brown anus situate at about $\frac{1}{3}$ of their length; black brown chitinous patches on the festoons, largest on the penultimate; spiracles long comma-shaped. *Capitulum* (0·9 to 1·1 mm. *l.*) with base long, broader in front, the external angles anterior and only slightly salient; cornua moderately salient; a transverse



A *B* *C*

Fig. 17. *A* ♂ dorsum to show hairs on surface, *B* the same, to show surface texture, *C* the same, ventral aspect (anus slightly too posterior).

row of long hairs continued on the antero-lateral borders; palps short and compact, articles 2 and 3 with small sharp lateral angles, fringed with hairs; parallel retrograde processes on the ventral surface of articles 1; hypostome 3|3. *Legs* red brown, hairy; coxa I prominent in front and with two long spurs, the

inner the stronger; coxae II and III with outer spur and rounded inner blade; two small sub-conical spurs on coxa IV.

Fig. 18. ♀ capitulum and scutum.

Female, L. 3·5, W. 2·2 mm. (unfed), L. 4·4, W. 3·5 mm. (partly fed, the largest). *Body* dark brown. *Scutum* (Fig. 18) (1·6 × 1·8 to 2·1 × 2·2 mm.) nearly circular, with slightly sinuous posterior border; numerous small uniform punctations; some of them confluent; on the posterior part of the scutum, a few larger

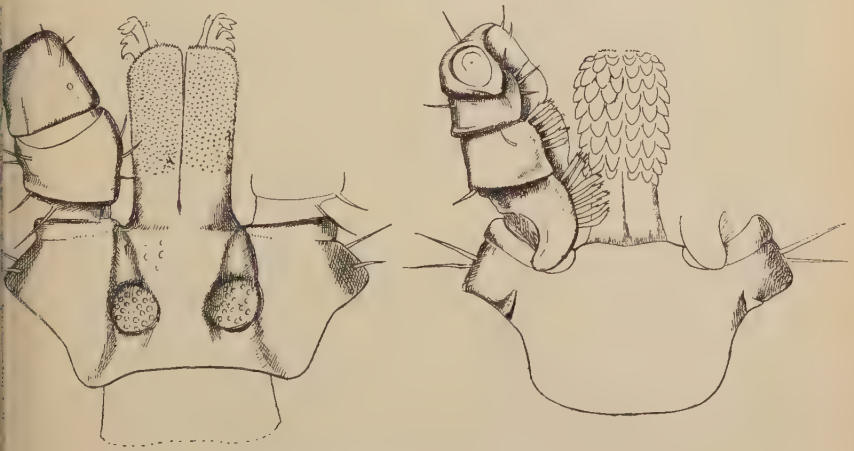


Fig. 19. ♀ capitulum, dorsal and ventral aspects, ·9 mm. *l.*

between the cervical grooves and outside the lateral groove; hairs shorter than in ♂ and very caducent, but similarly arranged; spiracles short comma-shaped. *Capitulum* (Figs. 18 and

19) (0·9 mm. *l.*) as in ♂ but with base shorter and broader; with circular porose areas. *Legs*: coxae as in ♂, but weaker.

Origin. Description based on 2 ♂ and 6 ♀ collected in North Nyassa, British Central Africa, by Dr Old, 1907; 1 ♂ (the larger) from Benguella, W. Africa, collected by Dr F. C. Wellman, 1907. Hosts not stated. (Preserved in 4 °/₀ formalin, transferred to spirit.)

Fig. 20. ♀ digit, 145 μ *l.*

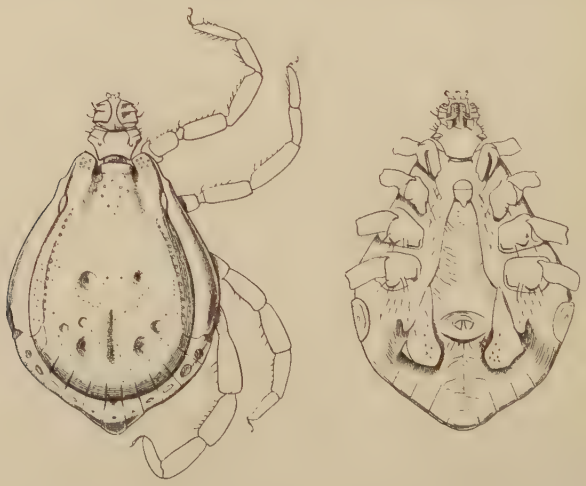
Note.—Digit of ♀ (Fig. 20) 145 μ long; dorsal process broadening outwardly into two conical teeth, external article bidentate.

Near *R. capensis.*

Rhipicephalus masseyi n. sp.

Figures 21—26.

Male, L. 2·8, W. 1·8 mm. (small, unfed) to L. 4·3, W. 2·6 mm. (large, gorged). *Body* (Fig. 21 gorged) narrow anteriorly widening greatly to level of spiracles, then tapering to blunt caudal protuberance involving three central festoons. *Scutum* glossy, bluntly rounded behind, many shallow punctations, especially on scapulae,



A *B*

Fig. 21. ♂, *A* dorsal and *B* ventral aspects.

between cervical grooves, in marginal grooves and on festoons; cervical grooves deep crescentic pits, followed by shallow divergent depressions; lateral grooves not well-marked, represented

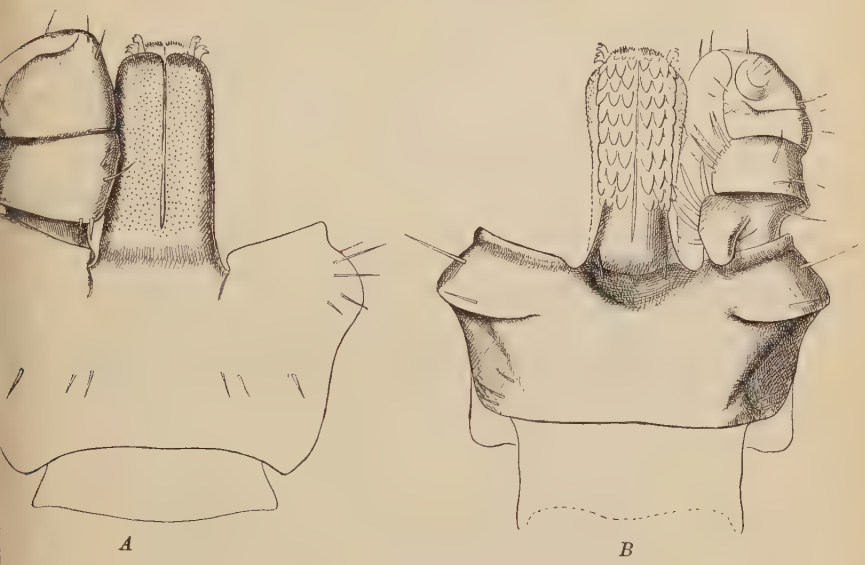


Fig. 22. ♂ capitulum, *A* dorsal and *B* ventral aspects.

anteriorly by punctations; two pairs of shallow depressions, the anterior at mid-length, the posterior on either side of median posterior groove (as in *R. sanguineus*); foveolae small, circular, far apart, between anterior depressions*. *Venter*: spiracles (Fig. 25)

Fig. 23. ♂ tarsus IV. ×35.

Fig. 24. Digits of *A* ♂ and *B* ♀ respectively 140 μ and 120 μ *l.*

blunt comma-shaped; adanal shields roughly isosceles with rounded angles but sometimes protruding at inner angle; accessory shields

* Indicated by 2 black points in Fig. 21 *A*.

small bluntly triangular points; anus about midway between shields. *Capitulum* (Fig. 22): base rather long, lateral angles somewhat anterior; palps as long as hypostome, article 1 visible and giving palp a strangulated appearance (as in *R. bursa*); articles 2 and 3 each bear five or six flattened hairs on internal ventral margin; hypostome: corona finely toothed, dentition 3|3, eight teeth per file. *Legs* rather long and slender; coxa I two-spurred, the inner spur much stronger; very slight rounded spurs at the postero-lateral angles of coxae II—IV; tarsi (Fig. 23) bluntly tapering with two small consecutive spurs.

Female, largest specimen L. 11·6, W. 8·9 mm. (smallest, slightly fed, L. 3·6 mm.) somewhat square when full fed. *Scutum* (Fig. 26; see Note) short oval, nearly circular, glossy, uniformly punctate; cervical grooves as in ♂ with somewhat longer posterior depressions; no lateral grooves; foveolae the same size as in ♂. *Capitulum*: lateral points more pronounced than in ♂; porose areas oval, medium-sized; palps, digit, spiracles (Fig. 25) and legs approximating to those of ♂.

Fig. 25. Spiracles of ♂ and ♀ respectively 750 μ and 470 μ *l.*

Fig. 26. ♀ capitulum and scutum.

Origin. Description based on 31 ♂ and 21 ♀ from *Bos caffer*, Kansanshi, N.W. Rhodesia, collected by Dr A. Yale Massey, 1907 (preserved in spirit).

Note.—The greater or less prominence of the *caudal protrusion* depends upon the state of repletion. In unfed specimens the body projects but slightly beyond the scutum and conforms with its contour there being no protrusion, whilst in large gorged specimens the protrusion may measure ·5 mm. *Capitulum* of ♂ ·7 to ·8 mm. *l.* *Scutum* of ♀ 1·4 to 1·7 *l.*, 1·3 to 1·8 mm. *w.*, in some specimens more elongated. *Digit* of ♂ (Fig. 24 *A*) 140 μ *l.*, external article bidentate, dorsal process small with two blunt processes pointing outward. *Digit* of ♀ (Fig. 24 *B*) 120 μ *l.*, more compact than in ♂, dorsal process small and irregular, external article bidentate.

The recently described species *Rhipicephalus aurantiacus* Neumann, 1907 appeared to agree so closely with ours that it was necessary for us to refer our specimens to Prof. Neumann for comparison with the types of his species. He has kindly sent us the following notes with regard to the specific differences he has found:—

R. masseyi.	*R. aurantiacus.*
♂	♂
Scutum: punctations much fewer, shallower, lateral grooves distinct, short.	punctations, numerous, deeper, lateral grooves absent or formed by punctations.
Capitulum base: small, with lateral angles more anterior.	broad, short with lateral angles more salient, not so far in front of the middle.
Legs: weaker, coxa I weak.	stout, coxa I stout.
♀	♀
Scutum: smaller, with fewer punctations.	larger, with more punctations.
Capitulum base: relatively much longer, narrower.	broad, short.
Legs: weak.	stout, coxa I stout.

R. masseyi ♂ approaches to *R. ziemanni* but differs amongst other points as follows:—

R. masseyi ♂.	*R. ziemanni* ♂.
Capitulum base: lateral angles at anterior $\frac{1}{3}$.	lateral angles about half-way.
Legs—coxa I, external spur shorter than internal.	external spur at least as long as internal.

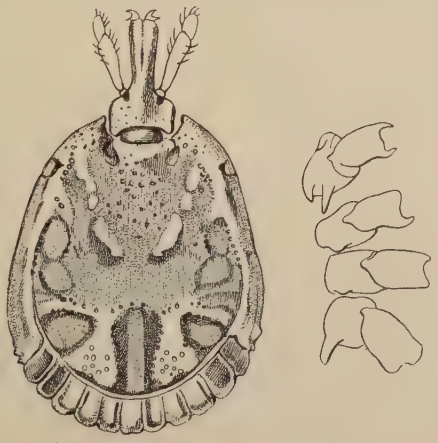
R. masseyi ♀ approaches more closely to *R. appendiculatus* but differs especially as follows:—

R. masseyi ♀.	*R. appendiculatus* ♀.
Scutum: lateral grooves absent.	distinct.

Amblyomma versicolor n. sp.

Figures 27—29.

Male, L. 3, W. 2·4 mm. *Body* oval (Fig. 27 *A*). *Scutum* covers the whole dorsum; ornate (see Note), tortoise-shell-like, with yellow-



A *B*

Fig. 27. ♂, *A* dorsal aspect, *B* coxae I—IV.

brown ground-colour variegated with metallic golden and dark brown markings (whence "versicolor"); the principal metallic lines radiate from a spot behind the centre of the scutum, an anterior pair marking a pseudoscutum; the principal dark brown markings are two crescentic spots internal to the eyes, a broad median posterior band, and a ring on either side of it; cervical grooves short; lateral grooves well-marked, complete; festoons long, narrow, well-marked, ornate; eyes pale, flat. *Venter* yellow; spiracles (Fig. 29) long comma-shaped, narrow, white; plaques present. *Capitulum* long (1 mm.), base broadly rectangular; palps long; hypostome equal in length to the palps, dentition 3|3, six teeth per file. *Legs* medium, yellow; coxa I (Fig. 27 *B*) bifid with sharp spurs, the outer longer, also a slight ventral spur in front; a single sharp spur at the inner angle of coxa IV; coxae II and III with very slight blunt spurs; tarsi like those of *A. cooperi* (Fig. 36).

Fig. 28. ♀ dorsal aspect.

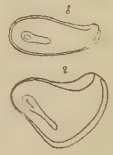


Fig. 29. ♂ and ♀ spiracles respectively ·5 and ·8 mm. *l.*

Female (fairly well fed), L. 8, W. 5 mm. *Body* (Fig. 28) mottled with yellow and brown, sparsely haired. *Scutum* cordiform (2·2 × 2·6 mm.) with metallic gold and dark brown markings; the latter along the cervical grooves, about the eyes, and along the postero-lateral margins; eyes pale, flat; each of the faintly marked festoons, except the median, bears a pale wart-like tubercle. *Venter* pale, hairless; spiracles (Fig. 29) short comma-shaped, pale brown. *Capitulum* (1·6 mm. *l.*) like ♂; hypostome with dentition 2|2; porose areas medium, oval. *Legs* like ♂.

ORIGIN. Description based on 1 ♂ and 1 ♀ from a horse, Tolosa, Oaxaca, Mexico, collected by Mr A. Laughton, 1907. (Preserved in 70 °/₀ spirit.)

Note.—Digit of ♂ similar to *A. atrogenatum* (Fig. 32). *Digit* of ♀ missing. *Spiracle* of ♂ ·5 mm., that of ♀ ·8 mm. long. *Colour*: dried for 48 hours the general coloration in the ♂ remains the same, the metallic spots appear a dull coppery colour. In the ♀ the metallic coloration also corresponds to the light portions of the scutum in Fig. 28.

Amblyomma atrogenatum n. sp.

Figures 30—32.

MALE, L. 4·5 to 5 mm., W. 3·5 to 4·5 mm. *Body* (Fig. 30) short oval, narrower in front. *Scutum* entirely covered with golden metallic sheen (see Note) except cervical grooves and a narrow dark brown line on each antero-lateral border (hence "atrogenatum") starting from scapulae, including the small yellow flat eyes, and ending at or before the spiracles; cervical grooves crescentic, convex outside; lateral grooves complete but only commencing just in front

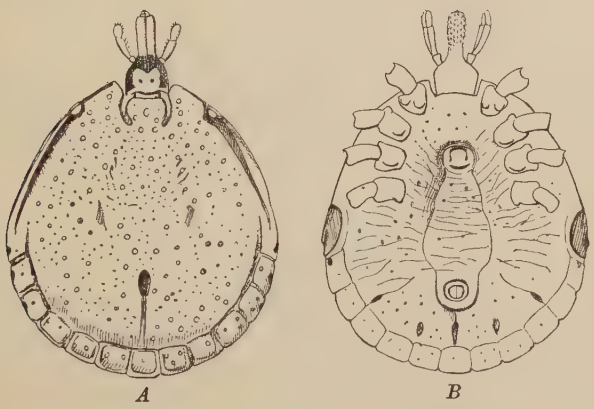


FIG. 30. ♂, *A* dorsal, *B* ventral aspects.

of spiracles; most specimens show three linear dark markings, one median posterior, two midway diverging in front. *Venter* pale, with dark brown anal ring and five well-marked chitinous plaques near posterior border; spiracles short comma-shaped. *Capitulum*: base triangular with a large golden patch dorsally, flanked by dark brown patches; posterior ridge straight; 1·2 to 1·6 mm. long; palps of medium length; hypostome (Fig. 31) equal to palps in length, dentition 4|4 merging into 3|3. *Legs* of medium length, pale dorsally, but showing faint annulations and dark markings

ventrally; coxa I with two flattened spurs, a single flat spur on the others, more pointed on coxa IV.

Fig. 31. Distal portion of hypostome, 335 μ *l.*

Fig. 32. Digit, 215 μ *l.*

Female, unknown.

Origin. Description based on 6 ♂ from *Testudo elegans*, received from India at the Zoological Gardens, London, 15. VIII, removed 2. X. 1905. (Preserved in spirit.)

Note.—Digit of ♂ 215 μ long (Fig. 32) dorsal process simply transverse, extending beyond the external article, the latter unidentate. *Colour*: dried for 48 hours the dorsum appeared of a dirty ochre colour with patches having a coppery metallic sheen underlying the ochre and visible at certain angles, the two dark linear spots situated on either side of the middle appeared larger and almost circular.

Amblyomma cooperi n. sp.

Figures 33—36.

Male, L. 3·4, W. 2·8 mm. *Body* (Fig. 33) oval, narrower in front, slightly impressed at level of eyes. *Scutum*: ground-colour yellow-

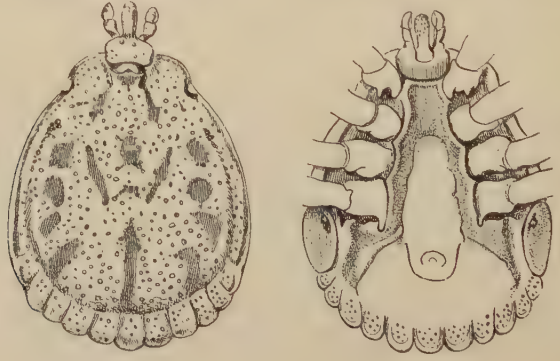


Fig. 33. ♂, *A* dorsal, *B* ventral aspects.

brown extensively white-enamelled (see Note); the dark markings are where the enamel is absent: along the cervical and lateral grooves, four spots on either side within the lateral grooves, and a rough *W* followed by an *I* in the median line; numerous rather fine punctations; cervical grooves small pits followed by shallow depressions; lateral grooves shallow, complete; eyes pale, flat. *Venter* white; spiracles large, oval, brown; plaques absent. *Capitulum* (1 mm. *l.*) base broader than long, ridge concave behind, white-enamelled dorsally; palps short; hypostome somewhat longer than palps, dentition 3|3, five teeth per file. *Legs* stout yellow-brown, mottled white; coxa I with two subequal blunt spurs; coxa IV single-spurred; tarsi with two terminal spurs, constricted at tip.

Female, L. 3·6, W. 2·7 mm. *Body* (Fig. 34) brown. *Scutum* large, cordiform (1·9 × 2 mm.) finely punctate; white-enamelled except

Fig. 34. ♀ dorsal aspect.

Fig. 35. ♀ digit, 195 μ *l.*

Fig. 36. ♀ tarsus IV. ×35.

cervical grooves, a median band, other small spots, one pair containing the eyes, all dark brown; eyes white. *Venter* yellow, the large oval spiracles whitish, white enamel at vulva and behind anus. *Capitulum* large (1·2 mm. *l.*), like that of ♂ but palps larger; hypostome 3|3, seven teeth per file; oval porose areas. *Legs* (Fig. 36) like ♂, but the spur on coxa IV is almost obsolete.

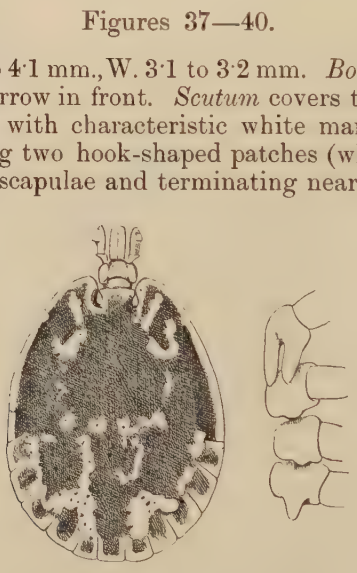
ORIGIN. Description based on 1 ♂ and 5 ♀ collected from "Carpinchio" (*Hydrochoerus capybara*) at Puerto Cooper, Alto Paraguay, S. America, by Mr W. F. Cooper in 1904. (Dry specimens.)

Note.—Digit (Fig. 35) of ♀ 195 μ long, dorsal process simply transverse, projecting on both sides, external article tridentate. *Colour*: placed 48 hours in 70% spirit the white enamelled areas (white in Fig. 34) on the ♀ scutum turned a light coppery colour.

Amblyomma uncatum n. sp.

Figures 37—40.

MALE, L. 3·7 to 4·1 mm., W. 3·1 to 3·2 mm. *Body* (Fig. 37 *A*) long oval, somewhat narrow in front. *Scutum* covers the whole dorsum; chestnut-coloured with characteristic white markings (see Note), the principal being two hook-shaped patches (whence "uncatum") beginning on the scapulae and terminating near the eyes, and two

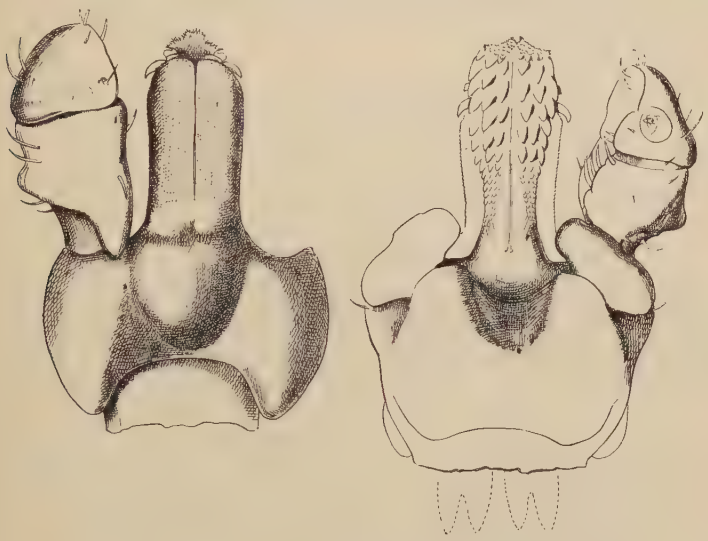


A *B*

FIG. 37. ♂, *A* dorsal aspect, *B* coxae I—IV.

curved patches connecting the first and third festoons on either side of the median festoon; other more or less obsolete small white spots limiting a pseudoscutum and connecting it by broken lines with the posterior patches; cervical grooves oval pits; no marginal grooves; festoons not deeply separated; punctations

numerous, medium; eyes pale, flat. *Venter* pale; spiracles (Fig. 40) ear-shaped, whitish, with dark brown border; no plaques; chestnut patches on the festoons; sexual orifice between coxae II; anal ring dark brown, a white semicircular area between it and the anal groove. *Capitulum* (Fig. 38) relatively short (1 to 1·1 mm. *l.*); base



A *B*

Fig. 38. ♂ capitulum, *A* dorsal, *B* ventral aspects.

broader than long dorsally with strong blunt cornua; palps short, article 1 very broad ventrally, article 2 projecting outwardly near the middle and with a strong retrograde process dorsally at its inner

Fig. 39. ♂ digit, 165 μ *l.*

Fig. 40. ♂ spiracle, ·55 mm. *l.*

angle; hypostome spatulate, dentition 3|3, about six teeth per file. *Legs* chestnut, the articles (except tarsi) annulated with white distally; coxa I (Fig. 37 *B*) with two subequal blunt spurs near together; coxae II—IV with small blunt spurs near the middle of the posterior border; tarsi with two terminal spurs.

Note.—Digit (Fig. 39) 165 μ long, very broad at dorsal process which protrudes transversely as a single dorsally-ridged tooth, external article bidentate with very large basal and small distal tooth. *Spiracle* ·55 mm. long. *Colour*: placed in spirit (70°/$_0$) for 48 hours the white markings turned a clean coppery tint and the general coloration became tortoise-shell-like, the chestnut coloured background being marked by dark blackish brown streaks along the antero-lateral margins, bordering the festoons and along the median line, with irregular dark lines running from the centre to the vicinity of festoons 4, 5.

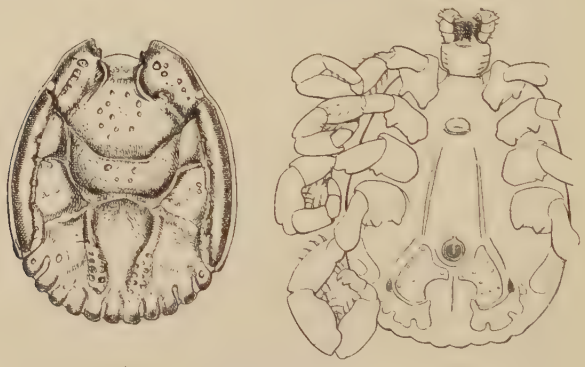
FEMALE, unknown.

ORIGIN. Description based on 5 ♂ from *Tamandua tetradactyla*, S. America. (Zool. Society's Gardens, London, 1905. Dry specimens.)

Hyalomma monstrosum n. sp.

Figures 41—45.

MALE, L. 4, W. 3·2 mm. *Body* (Fig. 41) dark brown, very highly chitinized. *Scutum* covering the whole dorsum, deeply emarginate, a pseudoscutum well-marked by a furrow; a second



A *B*

FIG. 41. ♂, *A* scutum, *B* ventral aspect.

furrow nearly parallel with this across the middle; from the posterior angles of this further furrows running towards the

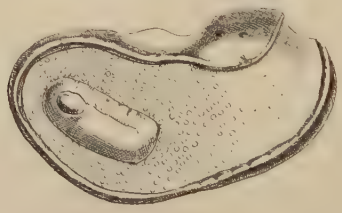
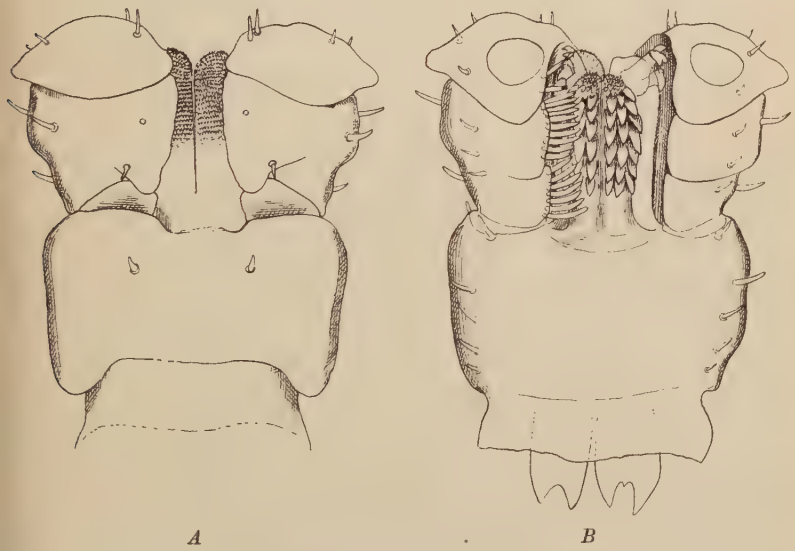


FIG. 42. ♂ spiracle, ·8 mm. *l.*

spiracles and towards the sub-median festoons; cervical grooves deep, crescentic, concave outwards; lateral grooves strongly marked, ending in front of the outermost festoon; several large deep punctations, especially on the scapulae, in the middle of the pseudoscutum, in the lateral grooves, and in the posterior furrows; eyes small, pale. *Venter* brown, sexual orifice large, between coxae II; spiracles ear-shaped (Fig. 42); adanal shields recalling



A *B*

Fig. 43. ♂ capitulum, *A* dorsal, *B* ventral aspects.

those of *H. aegyptium*, their curved anterior borders parallel to the anal groove, and nearly meeting behind the anus, punctate;

Fig. 44. ♂ digit, 163 μ *l.*

Fig. 45. ♂ tarsus IV.

accessory shields small chitinous points, each connected with a remarkable series of four festoon-like bags lying behind the anal

plates. *Capitulum* (Fig. 43) with sub-rectangular base only slightly broader than long (·7 mm. dorsally) and somewhat broader in front; palps short and of quite unusual shape, article 3 being bluntly protuberant laterally; hypostome 3|3, six strong teeth per file. (*Legs* see Figs. 41 and 45.)

FEMALE, unknown.

ORIGIN. Description based on 1 ♂ from a horse, Chin Hills, India, sent by Mr H. Maxwell-Lefroy, Imperial Entomologist of India, 1907. (Examined dry and then mounted in balsam.)

Note.—Digit (Fig. 44) 163 μ long, dorsal process transverse swelling to two blunt teeth, external article bidentate. *Spiracle* ·8 mm. long.

On the ionization of Gases by Ultra-Violet Light and on the evidence as to the structure of light afforded by its Electrical Effects. By J. J. Thomson, F.R.S., Cavendish Professor of Experimental Physics.

[*Read* 28 October 1907.]

The ionization of gases by ultra-violet light has been observed by Lenard (*Ann. der Phy.* I. p. 486, III. p. 298): in view of the importance of this effect in Meteorology however further experiments may not be superfluous. In working with tubes with a Wehnelt hot lime covered cathode I observed that the electric discharge when passing through the tube gave out large quantities of ultra-violet light, and this method of producing the light was adopted in the following experiments. The arrangement used is shown in Fig. 1. C is the Wehnelt cathode, A the anode; a quartz window P ·4 mm. thick was fastened to the tube by sealing-wax. The cathode was freshly covered with lime and raised to a white-heat. A potential difference of 300 volts, producing a current of about ·1 ampere, was generally used. The portion of the tube on which the window was fixed was inserted in a cardboard box B. The gas to be experimented on, after passing through drying tubes and a long cylinder of cotton wool to remove the dust, passed in front of the window and then between two concentric tubes E and F insulated from each other, the distance between the tubes was about 3 mm., the inner tube was connected with a tilted Wilson electroscope giving a deflection of about 40 scale divisions for a volt and the outer cylinder was charged up to 100 volts. The natural leak of the electroscope was determined with air in the ionization vessel and no flow of gas. The stream of gas was then passed without any discharge of electricity through the tube and a new determination of the leak made, so as to be sure that the gas was not ionized initially. No material increase of the leak was found, the discharge was turned on and several determinations made with the stream of gas on and off. The leak was now so marked that there was no difficulty in at once telling by the electroscope when the current of gas or the discharge was stopped or started. After the discharge and current were stopped a re-determination of the natural leak was made; this is necessary,

especially when using a gas like ammonia with which the insulation may fail at any moment.

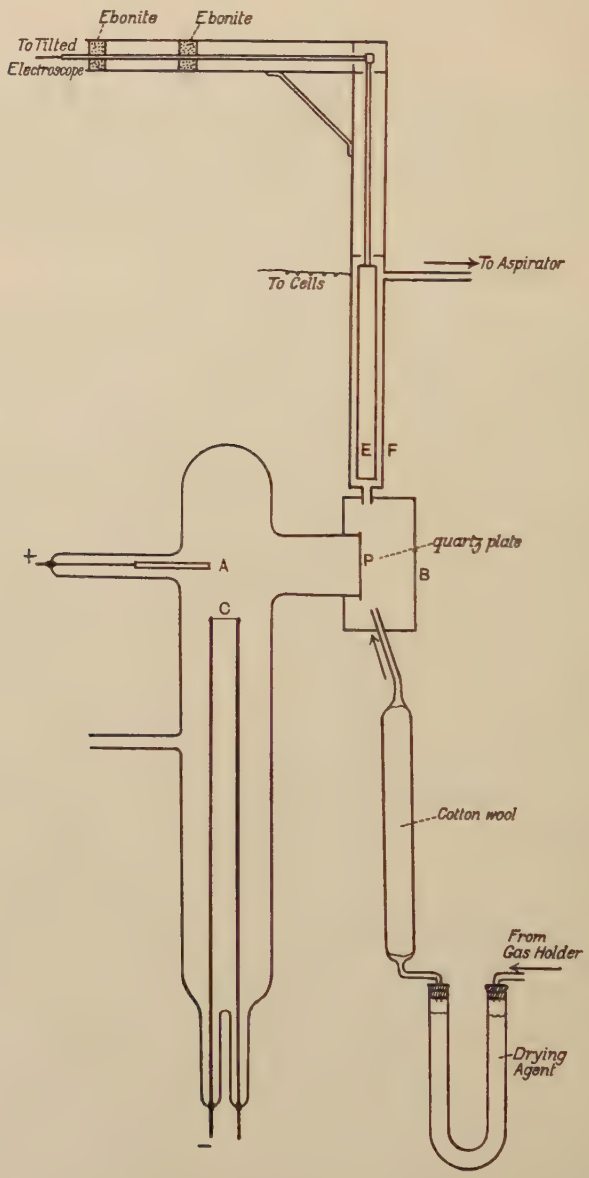


Fig. 1.

The results of the measurements were as follows:

In air, the natural leak was increased 8 times as the maximum, when the gas was exposed to ultra-violet light.

In carbonic acid gas, the natural leak was increased as much as 16 times by the ultra-violet light.

In ammonia, the natural leak was increased as much as 150 times by the ultra-violet light.

The ultra-violet light which produces this ionization is as Lenard has shown, absorbed by passing through a few millimetres of air at atmospheric pressure. If the box B were provided with a quartz window and P instead of going in the box were placed opposite the window it was found that the ionization was very marked when the distance between the windows was only 1 mm., but when the distance was increased to 3 mm. it became too small to be observed. We confirmed too Lenard's observation of the great absorption of coal gas by noticing that when the windows were 1 mm. apart the ionization was very much diminished by allowing a stream of coal gas to play between the windows.

Origin of the ultra-violet light in the tube. To find the relative amounts of ultra-violet light given out by the different portions of the tube the arrangement shown in Fig. 2 was used. The cathode C and the anode A were fixed together by a glass rod and the system floated on the mercury in a barometer column, the wires carrying the current to heat the cathode C dipped into side tubes filled with mercury. By raising or lowering the level of the mercury in the barometer column different portions of the discharge could be brought opposite to the quartz window P. Measurements of the amount of ionization produced in a stream of ammonia gas, which of all gases tried was the most ionized by the ultra-violet light, were made when all portions of the discharge from A to C were brought in succession opposite to the window. In this way it was found that by far the greater portion of the effective ultra-violet light came from quite close to the *anode*, the ionization when the anode A was opposite the window being three times as large as when the cathode C was opposite to it.

All the measurements in these investigations were made by Mr G. W. C. Kaye of Trinity College, to whom I wish to tender my best thanks.

The study of the electrical effects produced by light raises some very interesting questions as to the constitution of light waves, questions which hardly occur when we confine our attention to purely optical phenomena. I have already considered some of these in my *Conduction of Electricity through Gases* and also in *Electricity and Matter*. I pointed out that the fact that when Röntgen rays pass through a gas only an exceedingly small fraction of the molecules are ionized by the rays

suggests that these rays possess a structure, that the energy in them is localised in limited regions and that the great majority of the molecules of the gas escape ionization by being struck by the

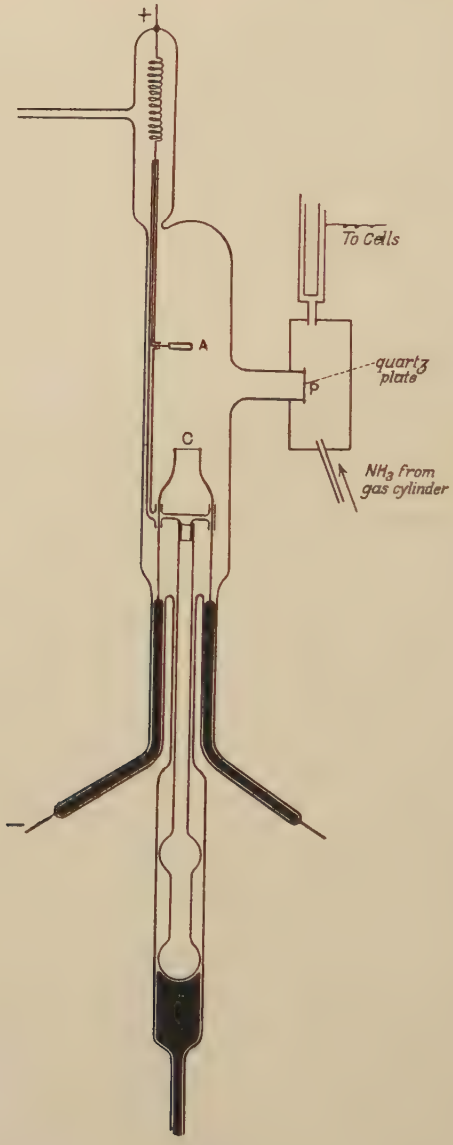


Fig. 2.

interstices between these regions and not by the regions themselves. That in fact the front of the disturbance corresponding to the Röntgen rays is not a surface of uniform illumination but resembles rather a series of bright specks on a dark ground. We can draw similar conclusions about the nature of light from the study of the effects of ultra-violet light either on the ionization of gases or on the emission of corpuscles from metal surfaces on which the light falls. The existence of the structure in the wave front implies that the ether through which the light is travelling has also a structure. We shall for the sake of definiteness make a special assumption as to the nature of this structure, and suppose that the ether has disseminated through it discrete lines of electric force and that these are in a state of tension and that light consists of transverse vibrations, Röntgen rays of pulses, travelling along these lines. Thus the energy travelling outwards with the wave is not spread uniformly over the wave front, but is concentrated on those parts of the front where the pulses are travelling along the lines of force; these parts correspond to the bright specks, the rest to the dark ground. There will not necessarily be a speck at each place where the lines of force cut the front, but only at those places where the lines of force happen to be in vibration at the instant under consideration. The energy of the wave is thus collected into isolated regions, these regions being the portions of the lines of force occupied by the pulses or wave motion. In fact, from this point of view the distribution of energy is very like that contemplated on the old emission theory, according to which the energy was located on moving particles sparsely disseminated throughout space. The energy is as it were done up into bundles and the energy in any particular bundle does not change as the bundle travels along the line of force. Thus, if we consider light falling on a metal plate, if we increase the distance of the source of light we shall diminish the number of these different bundles or units falling on a given area of the metal, but we shall not diminish the energy in the individual units; thus any effect which can be produced by a unit by itself, will, when the source of light is removed to a greater distance, take place less frequently it is true, but when it does take place it will be of the same character as when the intensity of the light was stronger. This is I think the explanation of the remarkable result discovered by Lenard, that though the number of corpuscles emitted by a piece of metal exposed to ultra-violet light increases as the intensity of the light increases, the velocity with which individual corpuscles come from the metal does not depend upon the intensity of the light. If this result stood alone we might suppose that it indicated that the forces which expel the corpuscles from the metal are not the electric forces in the

light wave incident on the metal, but that the corpuscles are ejected by the explosion of some of the molecules of the metal which have been put into an unstable state by the incidence of the light; if this were the case, the velocity of the corpuscle would be determined by the properties of the atom of the metal and not by the intensity of the light, which merely acts as a trigger to start the explosion. Some experiments made quite recently by Dr E. Ladenburg make, however, this last explanation exceedingly improbable. Ladenburg has investigated the velocities of corpuscles emitted under the action of ultra-violet light of different wave lengths and finds that the velocity varies continuously with the frequency; according to his interpretation of his experiments the velocity is directly proportional to the frequency. Thus, though the velocity of the corpuscles is independent of the intensity of the light, it varies in apparently quite a continuous way with the quality of the light; this would be very improbable if the corpuscles were expelled by an explosion of the molecule. It seems more reasonable to suppose that the velocity is imparted by the light, and yet as we have seen the velocity is independent of the intensity of the light. These results can however be reconciled by the view stated above that a wave of light is not a continuous structure, but that its energy is concentrated in units (the places where the lines of force are disturbed) and that the energy in each of these units does not diminish as it travels along its line of force. Thus if a unit by impinging on a molecule can at any place make it liberate a corpuscle, it will do so and start the corpuscle with the same velocity whatever may be the distance from the source when it strikes the molecule; thus the velocity of the corpuscles would be independent of the intensity of the light. Ladenburg found that the velocity of the corpuscle increases with the frequency of the light; this shows that if the view we are discussing is correct the energy in the units will increase with the frequency. This seems to be just what we should expect, for to take the analogous case of Röntgen rays, where thin pulses are analogous to light of short wave length, thick pulses to long waves, the thin pulses will have the greater energy for two reasons: (1) these pulses are produced by the collision of the more rapidly moving cathode particles which have more kinetic energy to be converted into radiant energy than the slower ones, (2) since the time of impact of the quick particles is smaller than that of the slow, a larger proportion of their kinetic energy will be converted into radiant energy. Considerations of a somewhat similar character indicate that in the case of light of definite wave length the energy in each unit will increase with the frequency of the light. Confirmation of this result is afforded not only by the experiments of Ladenburg

already alluded to, but also by those of Innes and Guggenheimer on the velocity of the cathode particles emitted by metals exposed not to light but to Röntgen rays. These observers have shown that the corpuscles emitted when the Röntgen rays are hard, i.e. when the pulses are thin, move faster than those emitted when the rays are soft, i.e. when the pulses are thick, and they showed that as in the case of light the velocity of the corpuscles is independent of the intensity of the rays. Since the thickness of a pulse of Röntgen radiation is very small compared with the wave length of even ultra-violet light we should expect much greater energy in the units in the Röntgen rays (and therefore much greater velocities of the corpuscles liberated by their action) than in the case of ultra-violet light. The experiments of Lenard and Innes show to how great an extent this is the case; the corpuscles emitted under the influence of the ultra-violet light used by Lenard had velocities of less than 10^8 cm./sec., while the velocity of those emitted under the Röntgen rays used by Innes had velocities approaching 10^{10} cm./sec., that is they had 10,000 times the energy of those emitted under ultra-violet light. It is probable that the corpuscles emitted under the action of the γ rays from radium have a still greater velocity and that therefore the units in the case of the γ radiation have enormously greater energy than those in the radiation corresponding to visible light.

We should know at once the coarseness of the structure corresponding to light of any intensity if we knew the amount of energy in each unit of light. To get some idea of this energy we may suppose that it is measured by the energy in the corpuscle liberated when the unit collides with a molecule of a metal. With the ultra-violet light used by Lenard the maximum velocity of the corpuscles was about 10^8 cm./sec., the energy of a corpuscle moving with this speed is about 3×10^{-12} ergs. Light of such intensity that 10^{-4} ergs pass one square centimetre per second would be very faint but would be visible if the light were in the visible part of the spectrum. In light of this intensity the number of units passing each square centimetre per second would be $10^{-4}/3 \times 10^{-12}$ or $3{\cdot}3 \times 10^7$, there would therefore only on the average be 1 unit in $3 \times 10^{10}/3{\cdot}3 \times 10^7$ or about 1000 c.c.; thus the structure of the light would be of an exceedingly coarse character, and could perhaps best be pictured by supposing the particles on the old emission theory replaced by isolated transverse disturbances along the lines of force. The greater the frequency of the light the greater is the energy in each unit, so that if it requires a definite amount of energy to liberate a corpuscle from a molecule of a gas, light whose wave length exceeds a particular value, which may depend on the nature of the gas, will be unable

to ionize the gas, for then the energy per unit will fall below the value required to ionize the gas.

The coarseness of structure of light even of feeble intensity is probably almost as nothing in comparison with that of the γ rays, for as we have seen the energy per unit in the γ rays is probably 10,000 times that in ordinary ultra-violet light. Thus the units in the γ rays will, unless the intensity is exceedingly great, be very widely separated; as these units possess momentum as well as energy they will have all the properties of material particles, except that they cannot move at any other speed than that of light. Thus we can readily understand why many of the properties of the γ rays resemble those of uncharged particles moving with high velocities.

Note on a method of demonstrating the syncytial appendages of the placental villi. By W. L. H. Duckworth, M.D., Sc.D., Jesus College, University Lecturer in Physical Anthropology.

[*Received* 3 February 1908.]

[Plate XIV.]

The human placenta of the later stages of pregnancy (6th or 7th months) provides material for a very rapid and effective method of demonstrating the appearance of syncytial masses of protoplasm. I have found the material and the method specially useful in making preparations for a number of students.

Wishing to exhibit the connexions of the syncytial outgrowths from the villi, with the parent stems, more clearly than is the case in sections of the placenta, I tried the effect of teazing the tissue. At first I did not realise how easily the villi can be teazed out, and therefore having removed a small block (a cube of about 5 mm.) from the uterine surface of a well-preserved formalin-fixed (6th month) placenta, I placed the tissue in strong nitric acid, so as to facilitate teazing. I found that with properly fixed material of this sort, very strong nitric acid can be used, so that even 25 °/₀ of pure nitric acid with distilled water does not impair the histological features of the villi. The mixture of phloroglucin with nitric acid (cf. Bolles Lee's *Microtomists' Vade-Mecum* (Haug's Method) p. 314, Ed. 6), gives very good results. After a somewhat prolonged immersion (3 days) in the acid, the block was well washed, and small fragments were stained in Delafield's Haematoxylin. This stain acts very rapidly, and with the smaller pieces the period of immersion in the staining fluid must be reduced to $\frac{1}{2}$ minute. After dehydrating and clearing, by any of the ordinary methods, the small fragments of the block were teazed out on slides, and mounted in Canada Balsam. The nuclei of the syncytial masses are stained intensely, and the connexions of these outgrowths with the villi are very strikingly displayed when the specimen is examined with a $\frac{1}{6}$ objective and ocular No. 2 or No. 3. Very beautiful specimens are also obtained (after the preliminary immersion in acid) by staining larger blocks for a longer period (10 days) in borax carmine or in a 10 °/₀ solution of Grübler's haemalum.

Subsequently I found that for class-work, the preliminary treatment with acid is unnecessary, so that the preparation of specimens stained with haematoxylin is very rapid and easy.

In examining specimens prepared in these ways, I have been

struck with the evidence they provide as to the growth-history of the syncytial appendages of the villi. The syncytial masses are first distinguishable as accumulations of nuclei within a definite and circumscribed area which may be at the side of the

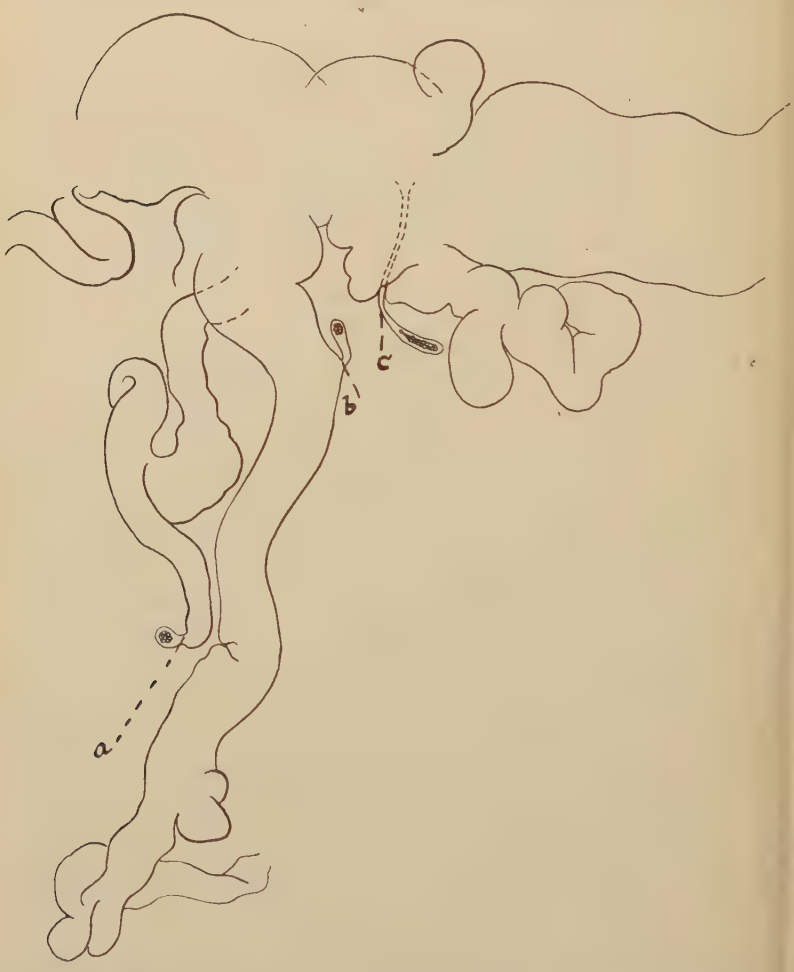


Fig. 1. Villi of a placenta of 6 months, bearing syncytial buds, which may be apical in position (as at "*a*") or lateral (as at "*b*" and "*c*"). [Cam. luc. Leitz. Obj. $\frac{2}{3}$, Oc. 2.]

villus, or in other cases at its extremity. This area becomes raised, and then forms a bud which enlarges and in particular

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

becomes elongated. Then a peduncle is formed, attaching the syncytial mass to its original site, and this peduncle may become astonishingly long. Three of these stages are represented in Fig. 1 (*a*, *b*, *c*.)

It is a matter for speculation, whether or no the syncytium at the extremity of the peduncle ever separates off and continues to exist as a detached giant-cell. So far as my observations go, they have not revealed evidence of the transformation of the syncytial mass into fibrinous striae, and I do not think that the points mentioned above as to the sequence of changes in the form of the syncytial appendages are clearly stated or emphasized in the ordinary descriptions of these structures. Systematic examination of placentae has now been commenced on the lines indicated, and this, I hope, will throw some light on the important problem of the later stages in the history of the syncytial masses. In the accompanying illustrations (drawn with the camera lucida) I have represented some of the typical appearances at different stages in the growth of syncytial masses in a placenta from a pregnancy of about 6 months. In villi from foetal membranes at about the ninth week, I find the syncytial buds less conspicuous, but they are present, and some have already acquired an attenuated peduncle.

DESCRIPTION OF PLATE XIV.

Figs. 2—7 incl. Various phases in the evolution of the pedunculated form of syncytial bud. The nuclei of the syncytia are stained more darkly than those of the other superficial cells covering the villi, and in Fig. 6 the darker nuclei are collected in the spherical bud, while the stalk attaching the latter to the apex of the villus is occupied by the nuclei of the ordinary villous ectoderm. [Cam. luc. Leitz. Obj. Zeiss D. Oc. 2.]

On the Intestinal Protozoan Parasites of Frogs and Toads. (Preliminary Communication.) By C. C. Dobell, B.A., Trinity College.

[*Received* 19 February 1908.]

Some time ago, I began an investigation of the life-histories of the Protozoa inhabiting the gut of the common frog and toad. And although my investigations are far from complete, it has become advisable for me to publish my results, as I shall be unable to continue the work for some months. I hope before long, however, to be able to publish a full account together with my drawings—without which my description is of necessity incomplete.

Such as is new, relates chiefly to the smaller Protozoa. I may briefly summarise my main conclusions as follows:—

A. Flagellates.

(1) *Trichomastix batrachorum* n. sp.

This new species is structurally almost identical with previously described members of the genus. The body is oval, and possesses an oval nucleus at the anterior end. Immediately in front of this lies a small chromatic body which I shall call the blepharoplast. From the blepharoplast arise the four flagella—three directed anteriorly, one posteriorly. Running backwards from the blepharoplast, and terminating in the caudal process, is an achromatic axial rod—whose function is probably skeletal. A cytostome is present at the anterior end of the animal.

Very large forms of this parasite are sometimes to be found. They are further characterised by possessing a very thick axial rod.

Multiplication takes place, in the gut of the host, by longitudinal division. The first event in the process is the loss of the axial rod. This appears to be dissolved and absorbed in some way. The blepharoplast then divides, two flagella going to either end of the dumb-bell figure which it forms. The nuclear membrane disappears, and the chromatin granules arrange themselves in a spindle-shaped figure round the strand connecting the two daughter blepharoplasts. The latter gradually separate from one another, the connecting strand increasing in size and remaining as a darkly-staining rod. Around the centre of the rod, the chromatin granules mass themselves, forming large, irregular, chromatic lumps. A division of the chromatin into two masses

then takes place, and one mass travels to each of the daughter blepharoplasts. In this region the chromatin masses subsequently fragment into small granules, a new nuclear membrane is formed, and the two daughter nuclei thus acquire the structure of the original nucleus. During this period, the blepharoplasts have been gradually drawing further and further apart—but still remain attached by the connecting rod. The external shape has also been greatly modified, being now roughly sausage-shaped—a nucleus and blepharoplast lying at either end, and the rod running longitudinally from one blepharoplast to the other. The new flagella are formed by out-growths from the blepharoplasts—two from either blepharoplast. The dividing organism remains for a short time in this condition, and then suddenly is constricted in two at the middle. Two rounded daughter monads result, each with an axial rod formed from a half of the rod which lay between the two blepharoplasts and was formed in the division of the parent blepharoplast.

It will thus be seen that the axial rod is reformed at each division, and does not arise in the daughter monads by splitting of the pre-existing organ. It is a product of the division of the blepharoplast.

If the organisms are taken from the gut of their host, or leave it in the faeces, they invariably die. Inside the host, however, they are able—under conditions which have not been ascertained—to form cysts. These cysts no doubt serve for the dissemination of the parasites.

The cysts are very small, and vary in size somewhat. Before encystment, the nucleus undergoes a change of structure, whereby a large karyosome is formed in it. The animal later becomes motionless, and loses its flagella. A cyst membrane is produced and gradually hardens. Inside the cyst, the axial rod degenerates. At a later stage, the nucleus becomes drawn out in a longitudinal direction so that it extends almost from one end of the cyst to the other. The blepharoplast persists as a little diplosomic body lying upon the nucleus.

In spite of much careful observation, I have never been able to observe an autogamy in the cysts. It will, indeed, be seen from my description that they differ entirely from those described in allied forms.

(2) *Trichomonas batrachorum* Perty.

I have reinvestigated the structure of this parasite, and find that it corresponds closely with that of the *Trichomastix* just described. The chief difference is the presence of an undulating membrane in place of the posterior flagellum. It arises from the blepharoplast and possesses a basal rod-like support which stains

like the nuclear chromatin. The relations of the axial rod are the same as in *Trichomastix*.

Multiplication occurs in exactly the same manner as in *Trichomastix*, save for the fact that the undulating membrane is probably multiplied by splitting—and not by a new growth, as in the case of the posterior flagellum. The behaviour of the blepharoplast and axial rod is exactly the same as in *Trichomastix*.

Hence my observations on the division of the trichomonads are very different from those of former investigators—e.g. Prowazek and Wenyon.

Trichomonas forms cysts which closely resemble those of *Trichomastix*, and in a closely similar manner. In the early stages, the nucleus (which also develops a karyosome) is visible as an oval structure, from which the axial rod passes backwards. Lying beside the nucleus are to be seen the darkly-staining edge and basal rod-like support of the undulating membrane. The flagella are lost, and the blepharoplast remains as a small diplosomic body upon the nucleus. At a later stage, the remains of the axial rod and undulating membrane disappear, and the nucleus becomes elongated, so that it is impossible to distinguish these cysts with certainty from those of *Trichomastix*. No further development has been observed.

I have seen no signs of any sexual process in these monads—nothing that in any way tallies with the conjugation noted by Schaudinn in *T. intestinalis*.

(3) *Octomitus* sp. (= *Hexamitus*, *Dicercomonas*, &c. of other writers).

Under this name I will describe the 8-flagellate monad which is frequently found in frogs and toads. No accurate description of this organism has yet been given.

Although very small (about 10μ long) it has a complicated structure. The shape of the body is a long oval, with the nucleus lying at the anterior end. The nucleus itself and its connexions are very complex, and do not appear to be always the same. A common condition is as follows:—At the extreme anterior end of the organism are two minute chromatin granules, lying side by side, and connected by a fine chromatic thread. From each granule a flagellum arises. Situated immediately behind this pair of granules, and connected with them by chromatic filaments, is another and a larger pair. To this pair are connected (1) a pair of flagella (on either side), (2) a large lobe of chromatin (one on either side) forming the main part of the nucleus, and (3) two axial rods. One rod passes backwards from each granule, and ends in another chromatic granule at the extreme posterior end

of the organism. From these two chromatic granules at the posterior extremities of the axial rods spring the posterior flagella, which may attain a length equal to three times that of the body.

Very minute forms of this parasite are sometimes found—not reaching a greater length than 2—3μ. The nucleus is usually less complex in these.

Multiplication appears to take place by means of longitudinal division, but is very difficult to observe.

Cysts of an oval shape are also found by *Octomitus*. From these cysts a single monad subsequently escapes.

No sexual process has been observed.

(4) *Monocercomonas bufonis* n. sp.

By this name I propose to designate a new 4-flagellate parasite which inhabits (on rare occasions) the large intestine of the toad. It is of an oval shape, with a large, rounded nucleus and four anteriorly-directed flagella. In length it measures about 15μ.

Details of the life-cycle have not been discovered.

B. Amoebae.

Two amoeboid organisms have come under my observation—one which appears to be a stage in the life-history of *Chlamydophrys stercorea* Cienkowski, and another which I may call *Entamoeba ranarum* Grassi, though it is by no means certain that Grassi really observed this organism.

The smallest forms of this amoeba are not more than 3—5μ in diameter, and are characterised by possessing a small ring-shaped nucleus with a central chromatic granule (karyosome). As they increase in size, the amoebae lose the former character of their nucleus, and come to possess a nucleus without a karyosome, and with chromatin granules evenly distributed throughout. At the periphery, however, larger granules are always present, so that the nucleus preserves its annular appearance. There is no contractile vacuole. The amoebae divide in the frog's gut, the nuclei dividing by a kind of very primitive mitosis. Although stages in division are very hard to obtain, the amoebae must divide with considerable rapidity, for frogs are occasionally found harbouring great numbers of the parasite.

The small amoebae, which continue to divide, appear to be capable of encysting: but the large actively-feeding animals—which may reach a diameter of 60μ or more—seem to lose the power of encysting, and always appear to degenerate and die. The nuclei of these large forms also undergo changes.

Before encystment, the nucleus of the amoeba develops a

karyosome, consisting of a few loosely-packed chromatin granules in the middle of the nuclear network. The amoeba then rounds itself off and forms a cyst membrane, which is at first very thin. Inside the cyst, a large vacuole makes its appearance, and a considerable quantity of a chromatin-like substance is to be seen lying in the cytoplasm. It appears to be extruded from the nucleus. The nucleus soon divides into two by a kind of primitive mitosis with the formation of a characteristic spindle figure. The daughter nuclei, which are much smaller than the original nucleus, divide once more, so that four still smaller nuclei are present in the cyst. In this condition the cyst remains for some time, each of the four nuclei having the appearance of a ring with a central dot of chromatin. Subsequently the chromatic bodies in the cytoplasm are extruded, and the vacuole disappears. The cyst-wall thickens and becomes yellowish, and the four nuclei undergo no further change. These are the permanent cysts which probably serve for the infection of other frogs. From the resemblance between the nuclei in the cysts and the nuclei in the smallest amoebae, it may be suggested that the cyst, on reaching a new host, liberates four small amoebae, just as the cysts of *E. coli* liberate a brood of eight.

Many of the cysts, whether liberated in the faeces or taken from the large intestine, appear to degenerate.

In *Entamoeba ranarum*, therefore, a very different series of events from those observed in *E. coli* and *E. muris* is to be seen. I have seen absolutely no indications whatever of an autogamy inside the cysts, as in the case of the two forms above mentioned. Although appearances similar to stages in autogamy are to be found—e.g. the two nuclear spindles during the second division—nevertheless, they have a very different significance. I cannot, therefore, in any way confirm the recent statement of Hartmann that an autogamy probably occurs in this form.

The amoeba-form of *Chlamydophrys* differs from *Entamoeba* chiefly as regards its nucleus. This consists of a large central mass of chromatin separated from the nuclear membrane by a clear zone.

The amoebae do not usually escape from the cysts in the frog, but do so after they have been liberated in the faeces. The amoeba-form subsequently develops a shell, becoming the typical *Chlamydophrys*—as already described by Schaudinn.

C. Other Protozoa.

Among the other Protozoa in the frog, I may record the presence of a hitherto undescribed *Coccidium*, which I propose to name *Coccidium ranae*, n. sp. I have only succeeded in dis-

covering the sporogony of this organism. Examination of the intestine, liver, and kidneys for stages in schizogony has had only negative results. The *Coccidium* resembles *C. salamandrae* Steinhaus, somewhat. There is a large oocystic residuum, each spore also containing a large sporoplasmic remainder. The spores are fusiform, and resemble those of *Monocystis* (which often pass through the frog's intestine) but differ, of course, in containing only two sporozoites. I have followed the development of the uninucleate oocyst up to the completion of the formation of sporozoites in the living animal, but have not been able to obtain stained preparations, owing to the extraordinary impermeability of both the oocysts and spores.

The sporozoites probably leave the spores in the upper part of the small intestine of their new host.

In conclusion, I may mention that I have observed—I believe for the first time—the cysts of *Nyctotherus cordiformis* Ehrbg. They are oval, of a greenish-yellow colour, and display a striation which follows the lines of cilia on the creature. Their length is about 80—90μ. The cytopharynx, nucleus, &c. remain unchanged inside the cyst. These cysts are probably the means by which infection of new hosts is brought about.

PROCEEDINGS

OF THE

Cambridge Philosophical Society.

The absorption spectra of some compounds obtained from pyridine and collidine. By J. E. Purvis, M.A., St John's College.

[*Read* 9 *March* 1908.]

The absorption spectra described in the following notes were obtained by means of the apparatus described by Purvis and Foster (*Proc. Camb. Phil. Soc.*, Vol. XIV. Pt IV. p. 381), in their investigations of the spectra of collidine and 9-chlorocollidine. Since then, the present writer has continued the study of several compounds obtained from collidine, together with a substance more directly related to pyridine, namely, 3 : 5 dichloropyridine, and the aim of this paper is to give an account of the results obtained.

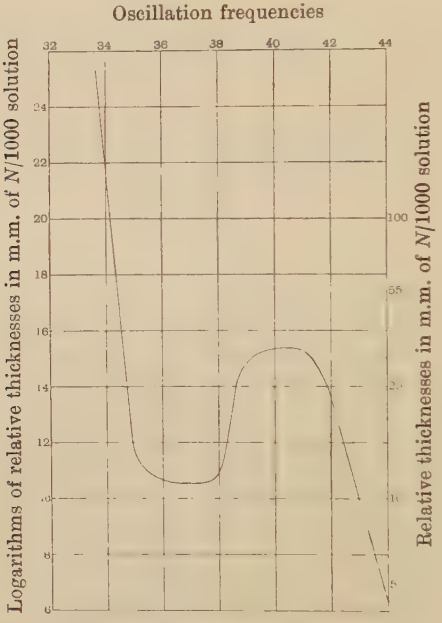
The absorption curves of 3 : 4 : 5-trichloropyridine, 2 : 3 : 4 : 5-tetrachloropyridine, and 5-chloropyridine have been already investigated by Baker and Baly (*Journ. Chem. Soc.* Vols. 91 and 92, pp. 1122—1132), and they found that the introduction of chlorine atoms into the nucleus produced a gradual shift of the band towards the red end of the spectrum, and that the persistence of the band was greatly increased, according to the number of the atoms introduced.

Dichloropyridine. It follows that dichloropyridine should form, as it were, a link in the series, and that the shift of the band should be less than that of trichloropyridine, and therefore, still less than those of tetra- and pentachloropyridines, whilst its persistence should not be so well marked.

Now, on examining the curve, plotted in exactly the same way as before, it is clear that such results have been obtained. On comparing it with the curves obtained by Baker and Baly (*loc. cit.*) of the before-mentioned chlorine derivatives of pyridine, there appears to be a shift of the band towards the red end, but it is not so marked as in the other chlorine compounds; and, also, the persistence of the band is also slightly less than that of the trichloropyridine, and therefore less than those of the tetra- and pentachloropyridines.

The positions of the heads of the bands, expressed in oscillation frequencies, are cited in the following table:

3 : 5-Dichloropyridine	3700	(Purvis)
3 : 4 : 5-Trichloropyridine	3650	(Baker and Baly)
2 : 3 : 4 : 5-Tetrachloropyridine	3500	„ „ „
Pentachloropyridine	3400	„ „ „

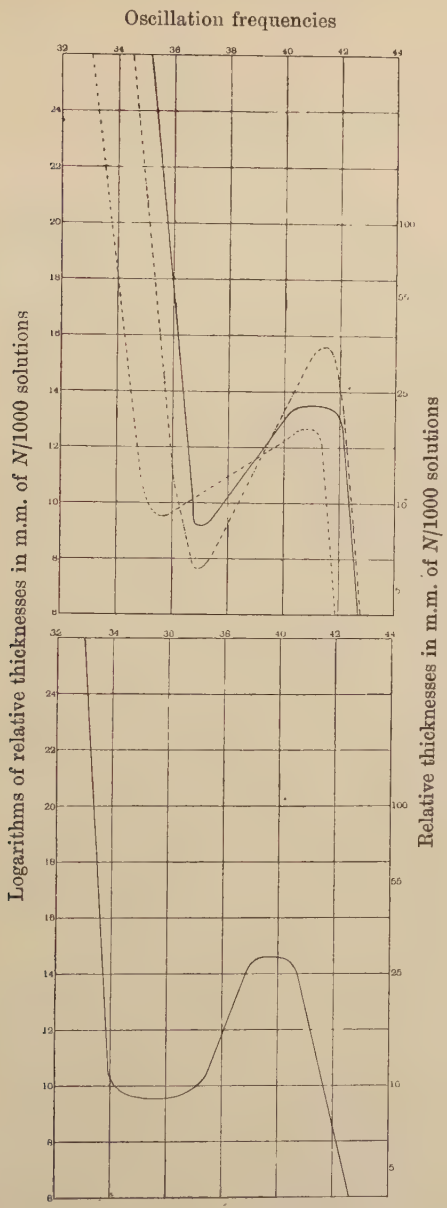


3 : 5-Dichloropyridine

The persistence of the band of the dichloropyridine compound is certainly less than that of the trichloropyridine, although the difference is not so well marked as appear to be the differences between the tri-, tetra-, and pentachloropyridines.

But the results obtained, from a study of the dichloropyridine, confirm generally the previous observations, namely, that the introduction of chlorine into the pyridine nucleus produces a gradual shift of the absorption band towards the red end of the spectrum; and the greater the number of chlorine atoms the greater the shift. And, also, that a gradually increasing number of chlorine atoms entering into the ring, produces a gradual increase in the persistence of the band.

Collidine hydrochloride. To turn now to the collidine compounds, the absorption bands of collidine and 9-chlorocollidine have already been described and discussed by Purvis and Foster


Oscillation frequencies
Logarithms of relative thicknesses in m.m. of N/1000 solutions
Relative thicknesses in m.m. of N/1000 solutions

I. Full curve: Collidine
Dotted curve: 9-Chlorocollidine
Dot and dash curve: Collidine hydrochloride

II. 7-Chlorolutidine

(*loc. cit.*), and it will suffice to refer to their paper for the details. With regard to the 9-chlorocollidine the examination and comparison of the absorption curve appeared to suggest the great probability that the nine chlorine atoms had replaced the hydrogen atoms of the three methyl groups, and that none had entered the nucleus.

The curves of these two compounds have been drawn again in order to compare them with the compounds investigated since.

It has been noticed by Hartley, and by Baker and Baly, that the addition of hydrochloric acid to the solutions of pyridine and of 2 : 6-lutidine, produces a very great increase in the persistence of the absorption bands, in addition to shifts of the band towards the red end.

The present writer has investigated the effect of adding hydrochloric acid to collidine ; and it will be noticed, from an examination of the curves, that precisely the same effect was obtained as in the case of pyridine and lutidine. That is to say, the introduction of hydrochloric acid to the collidine produces a very marked increase in the persistence of the absorption band ; whilst, at the same time, there is a slight shift of the band towards the red end. The persistence is, also, much less than that of either lutidine or pyridine hydrochlorides, and corresponds, *pari passu*, to the decreased persistence of the bands of collidine, lutidine and pyridine when these substances are examined in solution in the basic condition.

Baker and Baly's theory is that the addition of the acid satisfies the residual affinity of the nitrogen atom in these compounds, and thereby removes the restraining influence. Consequently the tautomeric process is increased, and the persistence of the band is increased. Now, Purvis and Foster (*loc. cit.*) have shown that, as the number of methyl groups in the pyridine nucleus is increased, the persistence of the bands is also decreased. That is to say, the persistence of the band of collidine (trimethylpyridine) is less than that of lutidine (dimethylpyridine), and still less than that of pyridine. Further, the increased persistence of the band of collidine hydrochloride is less than that of the lutidine hydrochloride, and, therefore, still less than that of pyridine hydrochloride.

The results, therefore, appear to indicate that, although the effect of the addition of acid to collidine is to increase the persistence of the band, it does not balance the restraining influence of the side chains. There appear to be two forces, as it were, acting in opposite directions. The vibrations of the ring are influenced in one direction, either by increasing the number of chlorine atoms in the nucleus, or by the addition of hydrochloric acid, by which increased persistence of the band is obtained ; and

they are influenced in an opposite direction, by an increase in the number and weight of the side chains, by which there is a correspondingly decreased persistence. And the weighting may be produced either by an increase in the number of radical groups as side chains, as for example, in lutidine or collidine; or by the substitution of the hydrogen atoms of these chains by chlorine atoms, as in 9-chlorocollidine.

7-chlorolutidine. Turning, now, to a substance obtained by Sell and Foster from 9-chlorocollidine, and called by them 7-chlorolutidine, the chemical investigation seems to show that, as it is derived from 9-chlorocollidine, six of the chlorine atoms have replaced the hydrogen atoms in the two methyl groups, whilst the remaining chlorine atom has entered the nucleus. A spectroscopic examination of its absorption band was undertaken to obtain some further information. The absorption curve has been plotted, and on comparing it with the curve of the 9-chlorocollidine, it will be seen that the persistence of the band has been considerably increased, whilst the shift is not quite so marked, but it is greater than that of either collidine or lutidine. The persistence also shows a greater increase than that of collidine.

The previous work has shown that, when two or more chlorine atoms are introduced into the pyridine nucleus, there is a very considerable and gradual increase in the persistence of the bands, according to the number of atoms introduced; whilst, when the chlorine enters the side chain, as appears to be the case in 9-chlorocollidine, there is a decreased persistence. Now, the persistence of the band of 7-chlorolutidine is certainly less than that of either the tetra- or pentachloropyridine. On the other hand, it is greater than either collidine or 9-chlorocollidine. And, therefore, in the chemical changes from 9-chlorocollidine to 7-chlorolutidine, the conclusion seems to be that at least one chlorine atom has entered the nucleus; whilst the other chlorine atoms have replaced the hydrogen of the two methyl groups of the side chains. The net result seems to be caused by the action of two forces acting in opposite directions tending to balance each other's influence.

The shift of the head of the band of 7-chlorolutidine towards the red end is 3600, expressed in oscillation frequencies; and that of the 9-chlorocollidine is 3580: i.e. the shift of the former is not quite so great as the latter. More exact conclusions can, perhaps, be drawn from the gradual shifts of the heads of the bands when they are the expressions of a similar series of bodies, like the various chlorine derivatives of pyridine already discussed. But when the compounds are like those of lutidine and collidine, the presence of the implied type of side chain, the replacement of

the hydrogen of the side chains by chlorine, or if, in addition, there are one or more chlorine atoms in the nucleus, all these factors may make the problem more complex. Nevertheless, the study of the increase or decrease in the persistence of the bands seems to be of some importance in reference to the constitution of substances: and the shifts of the bands by increasing the weight of the groups entering the nucleus, and also, it may be, the type of the substituted group, should be of additional value.

I have to thank Dr Sell for kindly giving me some of the substances examined: and also Mr W. H. Foster, who was good enough to make the solutions therefrom.

The limitations of the copper-zinc couple method in estimating nitrates. By J. E. Purvis, M.A., St John's College, and R. M. Courtauld, M.A., M.B., Pembroke College.

[*Read* 9 March 1908.]

Gladstone and Tribe (*Journ. Chem. Soc.* 1878, p. 140) proved that a copper-zinc couple quickly reduced an aqueous solution of potassium nitrate to potassium nitrite and ammonia. The observation confirmed a previous one by Thorpe that such a couple converted the whole of the nitrogen of nitre into ammonia. Several theories were suggested by the authors to explain the changes; and they were inclined to the view that, on the whole, the changes could be represented best by the following equations:

(1) $Zn\ NO_3K\,|\,NO_3K\,|\,Cu = Zn(NO_3)_2\,|\,K_2\,|\,Cu,$

(2) $K_2 + 2H_2O = 2KHO + H_2,$

(3) $KNO_3 + H_2 = H_2O + KNO_2,$

(4) $KNO_2 + H_6 = H_2O + NH_3 + KHO.$

The only nitrates investigated by them were potassium nitrate and ammonium nitrate. They did not investigate the changes when nitrogenous organic substances were also in solution with the nitrate.

M. Whitley Williams (*Journ. Chem. Soc.* 1881, p. 100) also investigated the action of a copper-zinc couple on nitrates; and he suggested a method of estimating nitric acid in water analyses based upon his results. He pointed out further the influence of temperature and of varying amounts of substances like lime, calcium sulphate, sodium chloride, and phosphoric acid when these are in solution with potassium nitrate. But the influence of dissolved organic substances containing nitrogen was not investigated.

It is probable that the estimation of nitrates by the copper-zinc couple is reliable, provided the waters have inorganic substances only in solution, and little or no substances of an organic nature. But when waters contain the latter compounds, as, for example, sewages, sewage effluents, or waters polluted by animal or vegetable refuse, it seems probable that the effect of the couple might influence the breakdown of organic substances containing nitrogen, and, particularly if the latter are in an unstable condition, one of the results would be the production of ammonia; and it would be a fictitious one so far as it affects the estimation of nitrates. For the ammonia estimated would be the result, not

only of the reduction of nitrates to ammonia, but also the reduction of a portion of the nitrogenous compounds usually called albuminoids.

So far as we know, no experiments have been published to investigate such possible changes; and the aim of this paper is to describe a series of experiments we have conducted to show that a copper-zinc couple affects the estimation of nitrates, whenever there are complex nitrogenous substances present in solution at the same time.

In estimating nitrates in sewages and sewage effluents by the various accepted methods, it is a common experience to obtain discordant results; and our experiments appear to explain the causes as regards the copper-zinc couple method.

So far as the production of ammonia is concerned the investigation is divided into three parts: (1) the spontaneous decomposition of dissolved nitrogenous compounds, (2) the action of a copper-zinc couple upon such compounds, and (3) the action of a couple in presence of a definite amount of potassium nitrate previously added to the solutions.

Details of the experiments.

The preparation of the couples was obviously of paramount importance; and we followed closely the detailed instructions given by Dr McGowan and his assistants contained in the *Report of the Royal Commission on Sewage Disposal*, Vol. IV. Part V. p. 17 *et seq.* It will be sufficient to refer to that publication for the details. The couples were always exactly the same size and shape, and were introduced into well-stoppered bottles containing the solutions. These solutions varied in strength from 1 %, 0·5 %, 0·1 %, 0·01 %, 0·001 % of the different organic substances. The bottles and their 100 c.c. contents were placed in an incubator at a constant temperature of 25° C. for 24 hours. They were then removed, cooled, and the free ammonia estimated in the usual way by comparison with nesslerized standard solutions of ammonia. In several of the earlier experiments the incubated solutions were distilled in the usual way; but, as there appeared to be no advantage therefrom, the ammonia in the later experiments was at once estimated, except in the last sewage samples containing the added potassium nitrate, which were distilled. In all the operations, water was used containing no free ammonia, and the apparatus was always being continually tested for the absence of ammonia. Particular attention was given to the absence of organic substances in the sodium chloride added to the solutions containing the couples, so that there should be no contamination from dirt. The sodium chloride added to the couple solutions was always ignited for some time in a platinum dish.

In each series of experiments the bottles were exactly the same size and each bottle contained 100 c.c. of the solutions. In the first series A, one solution contained no couple, whilst the other bottle contained a copper-zinc couple. In the second series of experiments B, potassium nitrate of known volume and strength was added to the couple and solutions. The stoppers of the three bottles were always firmly inserted.

The dissolved organic substances were soluble peptones, blood serum, soluble albumin, containing neither nitrites nor nitrates. And a sewage was used in the later experiments also free from the latter substances, determined previously by other methods. In each series of experiments different samples of the various substances were always used.

A. In the first series, two experiments of each solution were conducted, one solution containing a couple and the other without, the latter being called the blank experiment. The first column of the following table gives the name of the substance and the strength of its solution; the second column indicates the amount of ammonia produced in the blank experiment; the third column that produced when the couple was present; and the fourth column the excess of the latter over the former.

Name of substance, and strength of solution	Amount of NH_3 produced in 100 c.c. in blank experiment	Amount of NH_3 produced in 100 c.c. when couple present	Excess of NH_3 produced by couple, in parts per 100,000
Peptone			
0·002 gm. per litre	0·0000071 gm.	0·0000086 gm.	0·0015 gm.
0·020 „ „	0·000040 „	0·000051 „	0·0110 „
0·020 „ „	0·000013 „	0·000024 „	0·0110 „
0·200 „ „	0·00060 „	0·00017 „	
The 0·2 gm. per litre putrified during the blank experiment, so that no real comparison could be made.			
Blood serum			
1·0 % solution ...	0·000011 gm.	very large excess	
0·25 % „ ...	0·000014 „	0·00006 gm.	0·0580 gm.
0·05 % „ ...	0·0000071 „	0·000025 „	0·0179 „

It is clear from the above numbers that ammonia is produced by the couple in larger amounts than when the solutions are incubated without the couple. The gases produced by the action of the couple assist the breakdown of the complex nitrogenous compounds in solution, and ammonia is one of the final products of the degradation.

B. In the second series of experiments three solutions were made: one contained a copper-zinc couple; the second a copper-zinc couple and a definite volume of a known strength of potassium nitrate; whilst a third contained the dissolved substance alone, with no couple and no potassium nitrate. In the sewage incubations, the absence of nitrates was first proved by the indigo method.

Name of substance, and strength of solution	A Amount of NH_3 produced in 100 c.c. in blank experiment	B Amount of NH_3 produced in 100 c.c. when incubated with couple	C Amount of NH_3 produced in 100 c.c. and including added KNO_3 and incubated with couple	D Excess of NH_3 in B over that in A in parts per 100,000	E Excess of NH_3 in C over that in B in parts per 100,000	F Amount of NH_3 equivalent to the nitric nitrogen added to C in parts per 100,000
Albumin	gm.	gm.	gm.	gm.	gm.	gm.
0·5 % solution	0·00224	0·0028	0·00297	0·560	0·017	0·60
0·1 % „	0·00004	0·00005	0·0007	0·010	0·650	0·60
0·01 % „	0·000013	0·00006	0·0012	0·047	1·340	0·60
0·001 % „	0·000002	0·00003	0·0004	0·028	0·170	0·12
Peptone						
0·1 % solution	0·000027	0·00007	0·00044	0·043	0·370	0·60
0·01 % „	0·000011	0·00002	0·00043	0·009	0·410	0·60
0·001 % „	0·000013	0·000054	0·00023	0·041	0·176	0·12
Sewage						
1·0 % solution	0·00021	0·00031	0·00137	0·100	1·060	0·60
0·1 % „	0·000008	0·000037	0·00037	0·029	0·243	0·60
0·01 % „	0·000005	0·000037	0·00014	0·032	0·103	0·12
1·0 % „	0·0000057	0·00009	0·00057	0·084	0·480	0·60
0·01 % „	0·000011	0·000023	0·00014	0·012	0·137	0·12
0·001 % „	0·0000043	0·00002	0·000015	0·015	0·160	0·12

The results of the preceding tables may be considered from two points of view. First, there is the excess of ammonia produced by the couple alone; and it is clear from the numbers in column D that the effect is to produce ammonia during the disintegration of the nitrogenous compounds in larger quantities than is produced when the couple is absent. It would be incorrect, therefore, to say

that such ammonia is produced by the reduction of the nitrates, for there were no nitrates present.

And, secondly, there is the effect of the couple when acting in the presence of potassium nitrate; and here the results are variable. In some instances the amount of ammonia produced is greater than would be produced by the reduction of the added nitrate, and in others it is less. In the former case the numbers indicate that the dissolved nitrogenous compounds have also been partly degraded; whilst in the latter case the meaning is not so clear, and it should be mentioned that in several incubations we noticed the presence of nitrites at the end of the experiments, indicating that complete reduction of the nitrates had not been accomplished.

To explain these results, it is suggested that it is not only the hydrogen liberated by the couple which influences the decomposition, but also partly the oxygen produced by the electrolytic action. Both elements would be in the nascent condition, and temperature and time would be conditioning influences of the total effect. Under these influences the degradation of the dissolved compounds would be greatly facilitated, with the production of free ammonia as one of the final products. If it were the result of an analysis of a sewage or of any solution containing considerable quantities of nitrogenous substances, it would be erroneously attributed to the reduction of nitrates.

With regard to the numbers obtained from the incubations in the presence of potassium nitrate, it may be that the effect of the couple is not always to isolate the nitrate or the nitrogenous substances and to complete the reduction of one before acting upon the other. It may be that the conditions of equilibrium of the organic compounds determine the direction of the reduction. In some instances the equilibrium may be such as to be easily affected by the nascent gases produced by the couple; whilst in others the effect is to act simultaneously on the nitrates and the organic substances so that both are only partially affected; and, within the time limits of the experiment, the complete reduction of the added nitrate would not be accomplished. Further, the increased ammonia, above that equivalent to the added nitrate, may be due partly to the oxidising influence of the nitrate itself; and this influence may be strengthened by the potash produced as the electrolytic action proceeds. So that the final result is caused by several influences; and the ammonia produced by the reduction does not represent that which is obtained from the nitrate alone.

Conclusions.

The above experiments, therefore, suggest some doubts as to the accuracy of the copper-zinc couple method for estimating nitrates and nitrites in waters heavily charged with organic nitrogenous compounds. The ammonia produced thereby does not represent the reduction of the nitrates and nitrites only, but also, partly, the complex nitrogenous compounds which undergo decomposition under the conditions of the experiment. No doubt, the amount of ammonia produced by the couple from the organic substances is small. But when it is necessary to search for small quantities of nitrates, and such an event has occurred in the authors' experiments with sewage (*Proc. Camb. Phil. Soc.* vol. XIV. pt. IV. pp. 354—360), these small differences cannot be neglected.

We desire to thank Miss Willcock, of the Physiological Laboratory, who kindly gave us the soluble albumin used in these experiments.

Description of a microcephalous new-born pig in which the face and the fore-parts of the brain were undeveloped, and the bucco-pharyngeal membrane remained imperforate. By W. L. H. Duckworth, M.D., Sc.D., Jesus College, University Lecturer in Physical Anthropology.

[*Read* 27 January 1908.]

[Plates XV, XVI.]

The specimen, Plate XV, Fig. 1, which forms the subject of the following communication was the only abnormal individual out of a litter of seven born at the usual term of pregnancy. I received the body in a perfectly fresh condition, though, as will clearly appear in the sequel, death must have been caused by asphyxia as soon as the umbilical cord had been severed. With the exception of the head, the body was found to be quite normally formed: this statement applies not only to the external conformation, but to the viscera and other anatomical structures so far as these were examined. The appearance of the head was sufficiently striking and abnormal. The ears were present, but the face was replaced by a smooth and rather spheroidal eminence, without eyes, nose or mouth (Plate XV, Figs. 1 and 2). On the anterior aspect of this eminence a small papilla was situated and from the surface of this, a tuft of fine hairs projected. The right (external) ear was not very different from a normal example except in that it was rather small. The left ear was distinctly smaller, and also thick and fleshy. It should be noted that although the ears were not separated by a wide interval on the ventral surface, yet they were quite distinct, no fusion having occurred at all. This distinctness and separation of the ears excludes such a monstrous example from the class known as Otocephalus (in which the ears are conjoined below the mandible). The absence of the respiratory openings and mouth led to the asphyxiation of the monster, so soon as respiration through the placental circulation was at an end.

On proceeding to remove the brain and spinal cord, I soon discovered that the skull was extraordinarily thick and dense. In form the cranium appeared globular (cf. Fig. 16) and removal of the encephalon was rendered rather difficult by the small size of the brain-case as well as by its thickness and density. After removal of the encephalon, it was noticed that the skull wall in the region of the petrous bones was converted into a modified osseous tissue of almost porcelain-like appearance and hardness.

The central nervous system after removal presented the remarkable appearance represented in Plate XV, Fig. 3 (a lateral

view from the right side). Evidently the brain was profoundly affected. An enlarged view of the lateral aspect of the brain is shewn in Plate XVI, Fig. 5, and I have also photographed the encephalon of a normal specimen employed as a "control." The right side of the abnormal specimen is represented in Fig. 5: in the normal example (Fig. 6) the left side is shewn.

In the monstrous pig, the brain was symmetrical, but consisted only of medulla oblongata, pons varolii and cerebellum, with the structures immediately connected with these parts. Moreover the cerebellum, and (to a less extent) the pons and the bulb, were reduced in size; the cerebellum fitted almost like a cap over the pons and bulb. The lateral parts were undeveloped and to this defect, the lack of mass of the cerebellum was chiefly due. The median part, or vermis, was therefore unduly prominent, but both this and the lateral portions were foliated.

The foreging points are illustrated by Figs. 7 and 9 (Plate XVI), which represent the ventral (Fig. 7) and dorsal (Fig. 9) aspects respectively. Figs. 8 and 10 shew the normal conformation of these parts.

The anterior aspect of the cerebellum was quite smooth. There was no suggestion whatever of any inflammatory process having been at work, and the tissues appeared perfectly normal in texture.

Thus it seems as though the brain was represented only by derivatives of the third primitive cerebral vesicle, and every observation pointed to the conclusion that we are here dealing with a case in which the second and the first vesicles had never been formed, not with an example in which after a brief course of growth these vesicles had retrogressed and degenerated. Evidently the arrest took place at the isthmus, a morphological frontier-line between the second and third cerebral vesicles. It is of importance to note that (as shewn in Fig. 3) the third cerebral flexure had occurred and was distinct.

The abnormal brain (including the bulb) was cut off from the spinal cord. After imbedding it in celloidin, I prepared a number of longitudinal sections of the whole brain, believing that it would be of interest to trace the central canal forwards as far as possible.

The appearance of a longitudinal section is shewn in Fig. 11 (a tracing made with Edinger's projection apparatus, from one of the mounted specimens). The floor of the central canal is represented by the upper border of the bulb, and it terminated as a distinct pit or depression (x) in the floor of the "fourth" ventricle (here the only ventricle). Anteriorly to this pit, the mass of the bulb will be seen in the drawing to run uninterruptedly upwards into the central portion of the cerebellum. In Fig. 12, I have reproduced a tracing from a section of the corresponding region

in the "control" pig. Upon a comparison of Figs. 11 and 12, it becomes evident that the pit or depression of Fig. 11 (x) is really only the expression of the very sharp and abrupt second cerebral

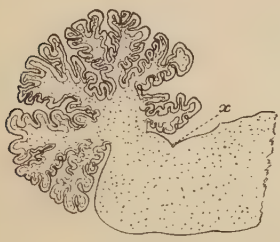


Fig 11.

Fig. 12.

flexure. In the series of longitudinal sections this pit-like depression varies however in its occurrence and this variability is just as pronounced in the normal as in the abnormal brain. This point seems to merit some further attention, for I observe that the

Fig. 13.

Fig. 14.

distinctness of the depression is not so great in the sections nearest the middle line. This rather paradoxical conclusion is supported by a comparison of Fig. 13 with Fig. 14. These are

both traced from sections of the hind-brain of the "control" specimen, and in Fig. 13, the depression (x) is quite deep, although as is shewn by the appearance of the mid-brain, the section is not in the middle line, and certainly not so near it as that shewn in Fig. 14. But in the latter the depression is not clearly marked. In the classical works on the embryology of the brain, there is some obscurity on this point, which however is not sufficiently important in the present connexion, to deserve more than a passing reference. The depression or pit is very distinct in the human foetal brain figured in the *Archiv für Anatomie*, 1892, Anatomischer Theil, Fig. 18, S. 401.

In the monstrous pig, the arrest of brain development had occurred in front of the third cerebral vesicle in the position of the "isthmus," and the second cerebral flexure had just made its effect felt. As is well known, this second flexure is dorsal in direction. It affects the region lying immediately in front of the pons varolii, though the latter structure is only partially affected by this influence. But just below this level the bucco-pharyngeal membrane is situated. In the present specimen, we have seen that the anatomical structures (viz. the central nervous system) on the dorsal aspect of the vertebral axis had been arrested in development at this level. And when attention is transferred to the structures on the ventral aspect, it will be seen that their growth also had been arrested quite definitely, and that the bucco-pharyngeal membrane had never been perforated.

Fig. 15.

Fig. 16.

Before terminating this account of the central nervous system, it is however interesting to refer briefly to the state of the spinal cord. Transverse sections of this structure were made in the cervical region (Fig. 15), and were found to differ in no particular from the control sections (Fig. 16). It is especially important to

notice that in absolute size, no appreciable difference obtains. And yet the cord of the abnormal specimen can receive no contribution from the cerebrum, since the latter did not exist. This observation seems to support the view that the pyramidal tracts of the cord are laid down *in situ* and owe nothing to fibres descending from the cerebrum. Moreover "Weigert" preparations reveal the presence of medullated fibres in those tracts.

After the central nervous system had been thus examined, the neck was dissected. The general appearances are shewn in Fig. 17, which represents the dissection on the right side. The

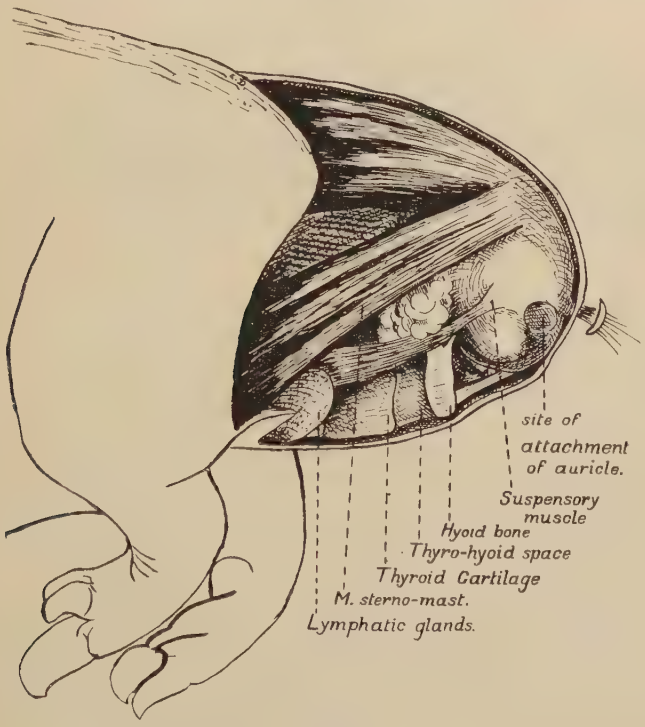


Fig. 17.

globular cranium gave attachment to a mass of nuchal muscles, and to the sterno-mastoid muscles. Anteriorly, the skull was quite imperforate and at this stage not the smallest trace of maxillae or mandible was perceptible. The hyoid bone and thyroid cartilage were quite distinct, however, and the hyoid bone was found to be suspended from the sides of the cranium by two symmetrical muscles (which are certainly not the Mm. stylo-hyoidei). Between these a mass of soft tissues closed in the pharynx.

A median longitudinal incision was then made, dividing the remains of the cranium, and splitting the neck into two equal halves. The appearance of the cut surface of the left half is reproduced (from a photograph) in Plate xv, Fig. 4, and in Fig. 18 I have sketched some of the main features in a semi-diagrammatic way.

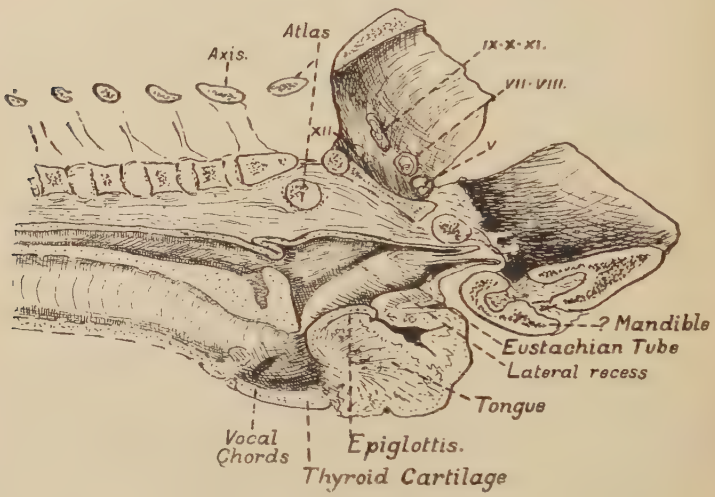


Fig. 18.

The base of the skull can be recognised (Plate xv, Fig. 4, and Fig. 18) and the bucco-pharyngeal membrane is seen in section. The pharyngeal part of the tongue is seen beneath this, and the epiglottis is large and distinct. In the retro-oral division of the pharynx, the lateral wall is marked by two grooves, which appear to correspond in position to the orifice of the Eustachian tube and to the lateral recess. Superiorly, a pharyngeal diverticulum ascended to the cranial base and represented the pouch of Seessel. The oesophagus, larynx, trachea called for no special description. The vocal cords can be seen. A large portion of the bucco-pharyngeal membrane attached to the root of the tongue with the epiglottis was then removed and examined microscopically. Fig. 19 represents the appearance of one of the sections under a low power.

The lining epithelium throughout is of the stratified squamous type. Similar epithelium lines the oesophagus and supplies a conclusive proof (if such is needed) that such epithelium may arise from endodermal tissue. The substance of the bucco-pharyngeal membrane contains much connective tissue with small glands and bundles of muscle-fibres, and this is of interest,

as shewing that although in the classical descriptions[1], the mesoderm is not supposed at first to intervene between the ectoderm and endoderm in this membrane, nevertheless it does

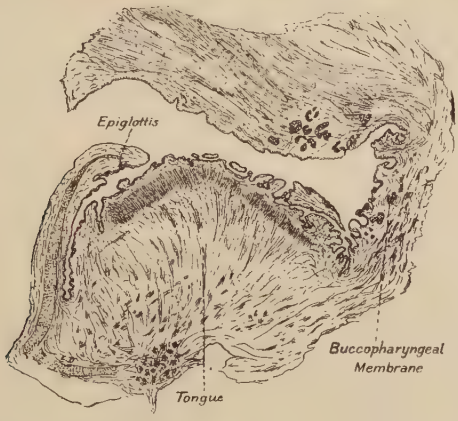


Fig. 19.

thus intrude at all events in such a case as that under consideration. The mucous membrane is thickest over the tongue, and it is here marked by more exuberant folds than elsewhere.

Such are the principal features of this remarkable specimen. Before adding any further notes by way of summarising the foregoing remarks, two points deserve attention.

(1) In searching for rudiments of the mandible, I found that the mass of bone marked (? Mandible) in Fig. 18 was in reality not part of the cranium as it had first seemed to be, but that it represents tissues formed anteriorly to the skull. Between this mass and the cranial base, soft tissue containing striated muscle fibres intervened and this may possibly represent the external rectus muscle of the eye, for a nerve corresponding in position to the sixth cranial nerve was seen to arise from the usual situation on the bulb. The connexion between the cranium and what I have termed the mass of bone, was lateral and not median. The mass is to some extent subdivided into upper and lower parts and each of these contained a gelatinous substance. From the lower mass, some of this jelly-like tissue was removed in an encapsuled state. This strongly suggested to me the probability of the nature of the gelatinous substance being dental, but microscopic examination gave me no aid in ascertaining whether this view were correct or not. The lateral attachment of the osseous mass to the undoubted

[1] Robinson in Cunningham's *Text Book of Anatomy*, 2nd Edition, p. 23.

cranium corresponds to a point immediately in front of the emergence of the fifth cranial nerve. In spite of the failure to provide an absolutely certain diagnosis of the nature of this bone-substance, I feel sure that it represents an aborted imperfect facial skeleton.

It remained to endeavour to identify the cranial nerves and a careful re-examination of the encephalon enabled me to make the sketch represented in Fig. 20. The cranial nerves which could be identified were

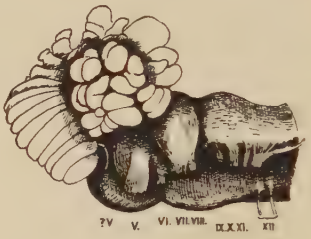


Fig. 20.

(*a*) The fifth (with sensory and motor divisions and an aberrant anterior division which looked rather like the fourth nerve: but in the absence of the orbit and its contents, as well as of the midbrain, I consider this filament to belong to the fifth).

(*b*) A nerve which I can only identify with the sixth; it seemed to go to the muscle immediately behind the osseous mass to which reference has been made in the preceding paragraph.

(*c*) The seventh and eighth together.

(*d*) The ninth, tenth and eleventh together.

(*e*) The twelfth nerve.

In reviewing the general character of this microcephalous pig, one sees that for some reason or other, the neural groove had never extended far enough forward to provide for the formation of the first and second cerebral vesicles, or else, that the latter had been formed, but that in the process of flexion of the nervous tube, they had become detached and had disappeared. I incline to the former of these two views, because those parts of the brain which had actually been formed, were smaller than usual, so that failure of the growth-power of the anterior part of the neural groove is suggested.

Secondly, the disturbance has been quite a local one and this statement is based upon the examination of the tissues and organs in general, as well as on that of the central nervous system in particular. Regarded as a case of microcephalus, this example falls into the category of those in which there is no diminution or arrest of development in the spiral cord (i.e. no micro-myelia).

At the same time, no pathological change marks such parts of the central nervous system as remain, so that this case does not fall into either class recognised by Giacomini in his study of human microcephali (*v.* the comments thereon by Cunningham and Telford Smith, *Sc. Trans. Roy. Dublin Soc.* Vol. v, Series II, pp. 289, 290, 338). It forms a good contrast in this respect with the case of microcephalus in the human subject (Cambridge Dissecting Room, 1905) described in the sequel (*Proc. Camb. Phil. Soc.* Vol. XIV, p. 478), wherein the cord was affected as well as the cerebrum.

Whether the perforation of the bucco-pharyngeal membrane is causally associated in normal cases with the great downward flexure of the anterior end of the brain with which it is contemporaneous, I am not able to state definitely, but that the connexion may be of this sort is a reflexion suggested by this specimen.

Cases of this kind are not unknown in domestic animals and are perhaps especially frequent in litters of pigs. The Hunterian Museum contains several comparable examples and with a note on these, this account will be brought to a close.

The specimens in the Hunterian Museum form part of the Teratological series, and are numbered as follows:—A 210, A 210*α*, Nos. 274, 275, 276, 280, 281, 282, 284—287 inclusive. On these specimens I made the following notes.

A 210 and A 210*α*. This is a human foetus. The conditions are almost exactly similar to those in the microcephalous pig here described. The bulb and pons were present, but no cerebellum or cerebrum. The third pair of nerves was thought to be present (cf. Catalogue). There is no note as to whether eyes were present or not.

No. 274. This is a young pig, and the conditions are very similar to those described above. Part of the cerebellum and possibly part of the cerebrum are present: the walls of the auditory capsules are of porcelain-like appearance (as in the Cambridge specimen), and closely approximated. The cranial cavity is rather larger than in the Cambridge specimen, otherwise the dimensions of the two are similar.

No. 275. Cranium of a young pig: general characters similar to those of No. 274 and of the Cambridge specimen.

No. 276. Cranium of a kitten: similar to No. 274.

No. 277. Cranium of a human foetus: similar to the foregoing, but probably some cerebrum was present.

No. 278. Head of a foetal lamb: the cerebrum is cystic: there is a general similarity to the foregoing specimens.

In these cases the tendency for the external ears to be united on the ventral aspect of the neck, is distinct (Otocephalus).

Nos. 280, 281. A foetal pig: almost identical with the Cambridge specimen, but the cranium is even thicker than in the latter. The cerebellum must have been very small. There was no cerebrum.

No. 285. A foetal hare. The cranium is represented by the occipital bone only.

Nos. 286, 287. Foetal pigs. The reduction at the cephalic extremity is less marked in these.

It thus appears that the anomaly represented by the Cambridge specimen is of a not uncommon type. But the descriptions and preparations of the specimens at the Hunterian Museum, leave something to be desired in the direction of more detailed anatomical demonstrations. In my description I have endeavoured to bring out a few of the very numerous aberrant morphological features presented by monstrosities of this kind.

Fig. 1.

Fig. 2.

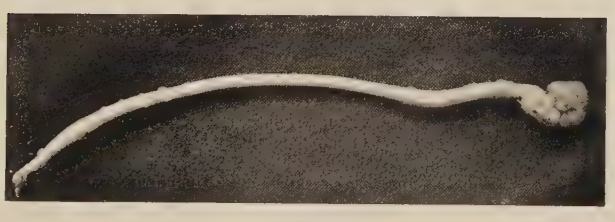


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

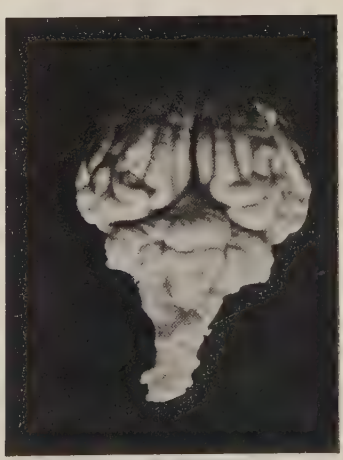


Fig. 10.

On six new species of Ixodidae, including a second species of the new genus Rhipicentor N. and W. By W. F. Cooper, B.A. Cantab, F.Z.S., F.L.S., and L. E. Robinson, A.R.C.Sc. Lond. From the Cooper Laboratory for Economic Research, Watford, Herts.

[*Received* 15 February 1908.]

This communication is a continuation of the descriptions of new species by Prof. G. H. F. Nuttall and Mr Cecil Warburton, published in the last issue of these Proceedings[1], and comprises hitherto undescribed ticks which the authors have encountered during their work on the Ixodidae in collaboration with the aforementioned.

List of New Species.

1. *Amblyomma longirostrum* (♀).
2. *Amblyomma caelaturum* (♂ and ♀).
3. *Rhipicentor nuttalli* (♂).
4. *Aponomma javanense* (♀).
5. *Aponomma simplex* (♂).
6. *Aponomma quadratum* (♂).

The authors use the same system of nomenclature and abbreviations as that given in the paper referred to above (pp. 392, 393).

Amblyomma longirostrum sp. n.

Figures 1—5.

Male, unknown.

Female (unfed), *L.* 4·9 mm., *W.* 4·3 mm. *Body* (Fig. 1) oval,

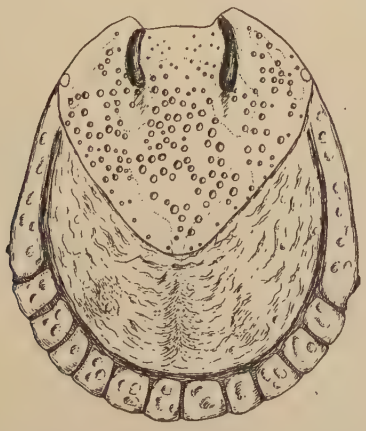


Fig. 1. *Amblyomma longirostrum* ♀, dorsal aspect.

[1] *Proc. Camb. Phil. Soc.* Vol. xiv. Pt. iv. pp. 392—416.

widest at level of spiracles, dull reddish-brown with darker irregular streaks, rugose, few scattered punctations, devoid of hairs: marginal grooves complete, deep; postero-median and accessory grooves short, not well defined; festoons well defined. *Scutum* (Fig. 1) sub-triangular, slightly broader than long (3 mm. × 3·1 mm.), dull yellowish-white with dark irregular patches near margins (light portions exhibit metallic iridescence after immersion in alcohol); punctations large, unequal, irregularly distributed; finer punctations between cervical grooves and towards margins; eyes flat and pale; cervical grooves short and deep; foveae indistinct. *Venter* less rugose than dorsum, with minute scattered hairs; spiracles (Fig. 2) irregularly triangular

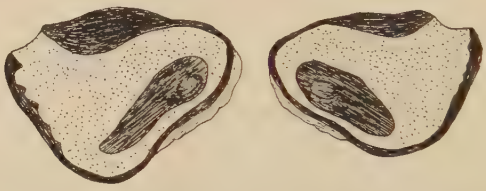
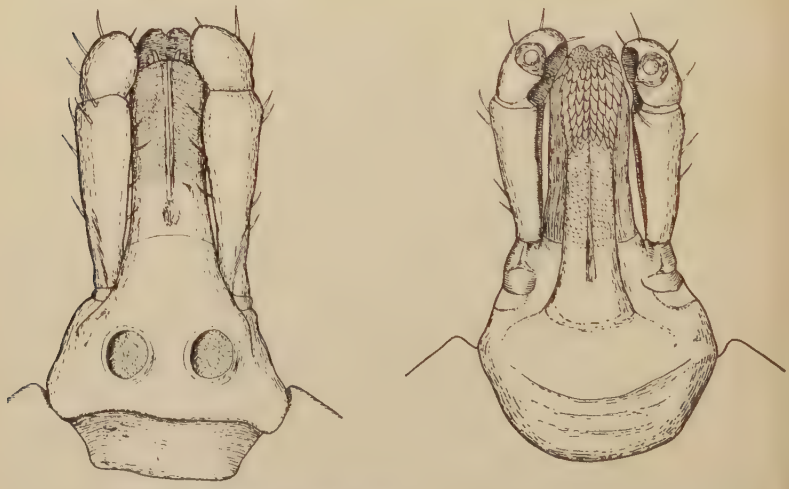


Fig. 2. *Amblyomma longirostrum* ♀. Spiracles, right and left, shewing discrepancy in size and shape.

with blunt angles, macula elongated. *Capitulum* (Figs. 3 and 4), *l.* 2 mm., basis capituli trapezoidal, porose areas circular, interval equal to diameter; palps long, second article more than three



Figs. 3 and 4. *Amblyomma longirostrum* ♀. Capitulum, dorsal and ventral aspects.

times length of third; hypostome as long as palps, dentition 4|4, tip emarginate and provided with a corona of minute irregularly-arranged denticles, minute squamiform denticles as usually seen in the genus, continued down shaft of hypostome towards base. *Legs* long; coxae (Fig. 5) each with two well-separated short

Fig. 5. *Amblyomma longirostrum* ♀. Coxae I.—IV.

blunt spurs; tarsi bicalcarate, those of 1st pair bossed on dorsal surface.

ORIGIN. Description based on one ♀ collected in British Guiana by Mr E. C. Foote. Host not specified. Preserved in alcohol.

NOTE. It is possible that this tick is the hitherto unknown female of *Amblyomma humerale* Koch, (*vide* Neumann, 1899, *Mém. de la Soc. zool. de France*, tome XII., pp. 230—231).

Amblyomma caelaturum sp. n.

Figures 6—9.

Male, *L.* 7·1 mm., *W.* 6.8 mm. *Body* (Fig. 6) almost circular, contour slightly indented and flattened on antero-lateral margins. *Scutum* dark brown with three metallic iridescent patches, one at

Fig. 6. *Amblyomma caelaturum* ♂, dorsal aspect.

either scapular angle and a single round spot at the postero-median angle of the pseudoscutum; scutum does not cover entire dorsum (protrusion of body laterally and posteriorly may vary according to the state of engorgement of the tick); coarsely and irregularly punctated, punctations numerous, confluent in places; small slightly elevated symmetrically arranged areas, devoid of punctations; cervical grooves deep and convergent anteriorly, shallow and divergent posteriorly; eyes dark, flat and indistinct; site of postero-median groove occupied by a smooth slightly elevated ridge, accessory grooves oblique, convergent anteriorly, short and deep; marginal grooves represented by linear arrangement of confluent punctations only; festoons large, well-defined, longer than broad. *Venter*, surface finely wrinkled; genital orifice between coxae II.; spiracles (Fig. 7) large, sub-triangular,

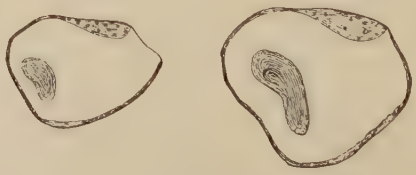


Fig. 7. *Amblyomma caelaturum.* Spiracles, ♂ and ♀.

angles rounded; plaques absent. *Capitulum* (*l.* 1·3 mm.), basis capituli rectangular, cornua very short; palps relatively short and thick, article 2 twice as long as article 3; hypostome shorter than palps, dentition 4|4, corona of minute denticles, emarginate at tip. *Legs* long and relatively slender; coxa I. with a pair of short blunt spurs, coxae II., III. and IV. each with a single short blunt spur; each of the free articles of the legs, with the exception of the tarsi, with an iridescent metallic spot at the distal extremity; tarsi attenuated at extremity; bicalcarate; tarsi of leg I. with three additional spurs of decreasing size in a proximal direction (Fig. 8).

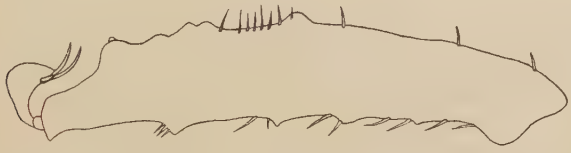


Fig. 8. *Amblyomma caelaturum* ♂. Tarsus I., .left

Female (gorged), *L.* 11·6 mm., *W.* 9·5 mm. *Body* oval, dark brown, covered with whitish hairs; marginal grooves absent, postero-median groove long, five pairs of short radiating grooves placed laterally, a single pair of parallel grooves immediately behind scutum; festoons large; foveae unusually large, appearing as a pair of salient plaques of light brown colour with dark margins on the middle of the dorsum. *Scutum* (Fig. 9) trian-

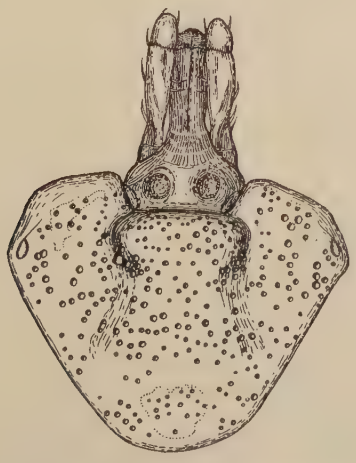


Fig. 9. *Amblyomma caelaturum* ♀. Scutum and dorsal aspect of capitulum.

gular, slightly broader than long (3·3 × 3·5 mm.), postero-lateral margins straight, posterior angle large and rounded, three metallic iridescent spots, one on either scapular angle, the third and largest, a round spot on the posterior angle; punctations large, fairly numerous, irregularly distributed and unequal in size; cervical grooves deep anteriorly, very shallow and divergent posteriorly; eyes as in ♂. *Capitulum* (Fig. 9) of medium length (2 mm.), basis capituli trapezoidal; porose areas deep, circular, interval rather less than diameter; palps longer than hypostome; hypostome relatively longer than that of ♂, dentition 4|4, emarginate at tip. *Venter* dark-brown, covered with whitish hairs; genital orifice small, between coxae II.; spiracles as in ♂ (Fig. 7). *Legs* as in ♂, tarsi slightly bossed on dorsal surface.

Origin. Description based on two ♂s and one gorged ♀. Collected by Mr F. F. Laidlaw, Skeat Expedition, 1899, Kwala Aring, Java. Host, a tortoise (*Geoemyda spinosa*). Preserved in alcohol.

Rhipicentor nuttalli sp. n.

Figures 10—14.

Male, *L.* 5 mm., *W.* 3·4 mm. *Body* (Fig. 10) oval, narrow in front, contour slightly concave just behind level of eyes; colour

Fig. 10. *Rhipicentor nuttalli* ♂, dorsal aspect.

dark reddish-brown. *Scutum* covers entire dorsum, glabrous, polished, punctations not numerous, coarse and shewing a tendency

to linear arrangement as in *Rhipicephalus simus*; numerous fine punctations at posterior end of body immediately anterior to festoons; cervical grooves short and deep, crescentic with convexity outwards; marginal grooves well-defined, commencing a little distance behind the eyes and terminating at the external festoon on either side; postero-median and accessory grooves shallow and ill-defined; eyes large and pale. *Venter* yellowish-brown with few scattered pale hairs; genital grooves parallel anteriorly, divergent behind coxae and extending to festoons; spiracles comma-

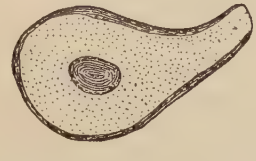
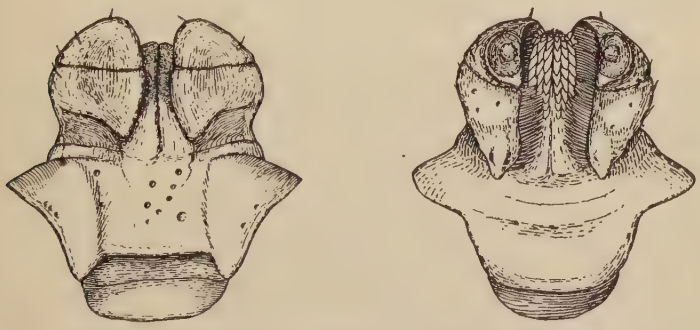


Fig. 11. *Rhipicentor nuttalli* ♂, Spiracle, left.

shaped (Fig. 11). *Capitulum* (Figs. 12 and 13) short (*l.* 1·1 mm.), basis capituli large, with pronounced lateral angles, cornua strong, short and blunt; palps short and broad, articles 2 and 3 rounded



Figs. 12 and 13. *Rhipicentor nuttalli* ♂. Capitulum, dorsal and ventral aspects.

laterally; article 2 bears a large triangular retrograde process on its ventral surface which extends backwards beyond the line of insertion of the palp; on its dorsal surface, a short blunt postero-internal process; slight ventral retrograde tooth on article 3; hypostome slightly spatulate, dentition 3|3. *Legs* strong; coxae (Fig. 14) spurred; coxa I. with two strong spurs placed close together, the internal pointed, the external, blunt; at the anterior angle a fold of chitin overlapping the trochanter; coxae II. and

III. with very stumpy blunt spurs; coxa IV. very large, with two long almost equal spurs, widely separated and slightly divergent,

Fig. 14. *Rhipicentor nuttalli* ♂. Coxae I.—IV.

the internal spur does not reach the anus; tarsi bicalcarate, spurs small and close together, distal spur terminal.

Origin. Description based on a single ♂ collected by Mr J. S. Looseley at Sandown, Rhodesia, South Africa. Host not specified. Preserved in alcohol.

This species differs from *Rhipicentor bicornis* N. and W. in the fact that it is shorter and 'squatter,' has more numerous and larger punctations, many fine ones at the posterior end of the dorsum; the lateral angles of the basis capituli are not nearly so pronounced, the palps are longer and the lateral margins of articles 2 and 3 are more rounded. The spurs on coxae II. and III. are more separated and blunter, those on coxae IV. are sub-equal, further apart and the internal spur does not extend as far back as the anus.

Female unknown.

Aponomma javanense sp. n.

Figures 15—17.

Male unknown.

Female, *L.* 5·3 mm., *W.* 3·6 mm. (unfed). *L.* 10·1 mm., *W.* 7·1 mm. (gorged). *Body* oval, wider behind than in front, dull yellowish-brown, punctate and sparsely covered with fine whitish hairs, marginal groove present, postero-median and accessory

grooves present; festoons well-defined. *Scutum* (Fig. 15) cordiform, broader than long (2·2 mm. × 2·9 mm.), no metallic markings; general colour light brown with darker coloration on lateral fields;

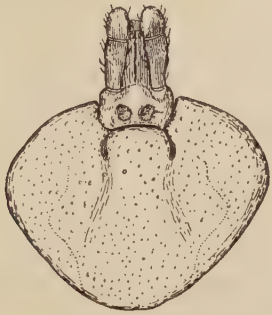


Fig. 15. *Aponomma javanense* ♀. Scutum and dorsal aspect of capitulum.

punctations fine, shallow and irregularly distributed; cervical grooves deep and crescentic with convexity outwards anteriorly, continued posteriorly by very shallow indistinct divergent grooves which do not extend to the posterior margin. *Venter*, genital orifice opposite interspace between coxae II. and III. in unfed ♀, opposite coxae II. in gorged ♀. *Capitulum* (Figs. 15 and 16) of medium

Fig. 16. *Aponomma javanense* ♀. Capitulum, ventral aspect.

size (*l.* 1·2 mm.), basis capituli nearly twice as broad as long, almost rectangular on dorsal side; porose areas small, elliptical

and obliquely placed, interval about two-thirds diameter; palps thick, longer than hypostome; hypostome short, slightly spatulate, dentition 3|3, large corona of minute denticles, emarginate at tip; spiracles triangular (Fig. 17). *Legs* moderately large; coxa I. with

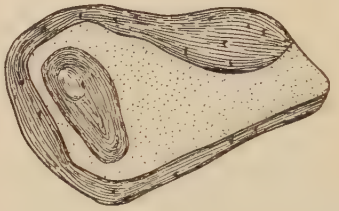


Fig 17. *Aponomma javanense* ♀. Spiracle, left.

two short blunt spurs, coxae II., III., and IV. with single short plate-like spur; tarsi bicalcarate, sharply attenuated at extremity, tarsus of leg I. slightly bossed on dorsal surface.

Origin. Description based on three ♀s collected by Mr F. F. Laidlaw at Biserat, Java, Skeat Expedition, 1899. Host, *Varanus salvator*.

Aponomma simplex sp. n.

Figures 18—21.

Male, *L.* 2·2 mm., *W.* 2·1 mm. *Body* (Fig. 18) nearly as

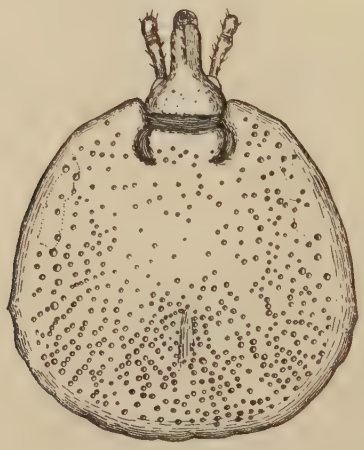


Fig. 18. *Aponomma simplex* ♂. Dorsal aspect.

broad as long, wider behind than in front, dorsum strongly convex. *Scutum* glabrous, punctate, punctations large, numerous on posterior half of the body; colour, dull ochre brown with an indistinct greenish iridescent patch on either side (indicated by the dotted lines in Fig. 18); cervical grooves short, deep and crescentic with the convexity outwards; marginal grooves absent; postero-median groove small, accessory grooves deficient; festoons not well-developed. *Venter* (Fig. 19) ochre-yellow, glabrous,

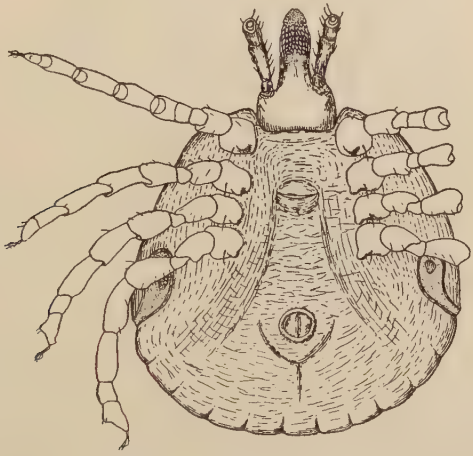


Fig. 19. *Aponomma simplex* ♂. Ventral aspect.

finely wrinkled; festoons better defined than on dorsum; genital grooves nearly parallel anteriorly, divergent behind coxae IV.; genital orifice large, situated opposite interspace between coxae II. and III.; spiracles comma-shaped (Fig. 20). *Capitulum* (Fig. 21)

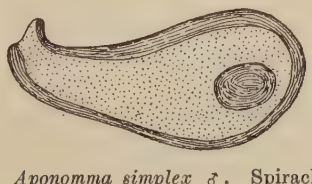


Fig. 20. *Aponomma simplex* ♂. Spiracle, right.

l. 0·9 mm.; basis capituli trapezoidal, cornua slightly developed; palps long, article 2 slender proximally; article 3 large; hypostome spatulate, corona of minute denticles, emarginate at tip, dentition 4|4. *Legs* relatively small, coxae (Fig. 19) each with a single short blunt spur; tarsi suddenly attenuated near extremity,

bicalcarate, bossed on dorsal surface; pads small, claws relatively long.

Female unknown.

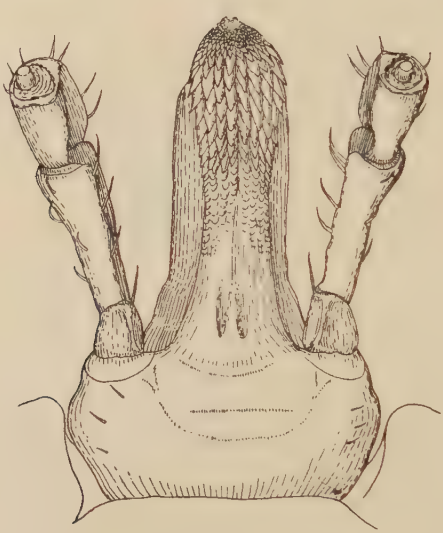


Fig. 21. *Aponomma simplex* ♂. Capitulum, ventral aspect.

Origin. Description based on one ♂ collected by W. F. Cooper at Quambone, New South Wales, Australia. Host, Iguana, species not given.

Note. Associated with *Aponomma Gervaisi* from which it differs more particularly in the dentition of the hypostome, the dentition of *A. Gervaisi* being 3|3.

Aponomma quadratum sp. n.

Figures 22—24.

Male, *L.* 2·6 mm., *W.* 2·8 mm. *Body* (Fig. 22) somewhat quadriform, wider behind than in front, broader than long. *Scutum* glabrous, punctate; dark-brown in centre, reddish-brown near margins; no metallic spots; punctations irregular, few coarse, many fine; cervical grooves short, deep, wide, straight and parallel; marginal grooves very indistinct; festoons well-marked, small, broader than long; nine shallow symmetrically disposed depressions on posterior half of scutum. *Venter* pale greyish-yellow, scattered with numerous whitish-hairs; genital orifice between coxae II.; spiracles (Fig. 23) large, ear-shaped, with short tail running round to dorsum. *Capitulum* (Fig. 22), *l.*

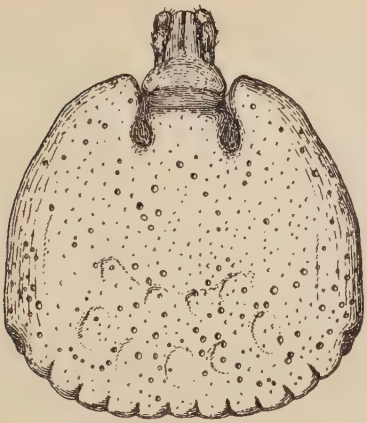


Fig. 22. *Aponomma quadratum* ♂. Dorsal aspect.

Fig. 23. *Aponomma quadratum* ♂. Spiracle, right.

Fig. 24. *Aponomma quadratum* ♂. Coxae I.—IV.

1 mm., basis capituli trapezoidal, cornua very short and blunt; palps short; hypostome with small corona of minute teeth, not emarginate at tip, dentition 3 3. *Legs* of moderate size; coxae (Fig. 24) spurred; coxa I. with a pair of short blunt spurs of which the internal is the longer; coxae II., III., and IV. each with a single short blunt spur; tarsi bicalcarate, sharply attenuated near extremity; slightly bossed on dorsal surface.

Female unknown.

Origin. Description based on a single ♂ collected by W. F. Cooper at Quambone, New South Wales, Australia. Host, an Iguana, species not stated.

Note. This species differs from *Aponomma ecinctum* in its possession of 3|3 rows of teeth on the hypostome and a *pair* of spurs on coxa I.; from *Aponomma crassipes* in the absence of greenish iridescent spots on the bosses of the tarsi.

The thanks of the authors are due to Prof. L. G. Neumann, of L'École Nationale Vétérinaire de Toulouse, to whom some of the foregoing new species were submitted for his opinion, before these descriptions were sent to press.

A Double Sulphate of Guanidine and Aluminium. By F. Ferraboschi, B.A., Clare College.

[*Read* 9 March 1908.]

In the course of some experiments upon the preparation of alums and other double salts of various organic bases, solutions of guanidine carbonate, aluminium sulphate, and sulphuric acid were mixed together approximately in the proportions that would be required for the formation of an alum. The solution was left to evaporate, and in the course of two days some crystals made their appearance. As these did not appear, from their shape, to be crystals of an alum, I undertook, at Dr Fenton's suggestion, an analysis of the substance with a view to ascertaining its composition.

It was found that both the guanidine and the aluminium had entered into its composition.

A quantitative analysis was then made with the result that it was found to possess the formula

$$(CN_3H_5)_2H_2SO_4 . Al_2(SO_4)_3 . 12H_2O,$$

or

$$CN_3H_5 . HAl(SO_4)_2 . 6H_2O.$$

The figures obtained were as follows:—

Experiment I. Determination of aluminium.

A weighed quantity of the substance was heated to a bright red heat in a platinum crucible until its weight became constant, and only alumina remained;

Weight of substance 1·9853 g.
Weight of Al_2O_3 ·2645 g.

Experiment II. Determination of sulphate ion.

This was precipitated and weighed as $BaSO_4$;

Weight of substance ·5611 g.
Weight of $BaSO_4$ ·6741 g.

Experiment III. Determination of nitrogen.

This was done by Dumas' method, the nitrogen evolved being collected and measured over 1 in 2 potash;

Weight of substance ·3410 g.
Volume of nitrogen obtained 32·5 c.c.
Temp. 18° C.
Bar. 759·1 mm.
Pressure of aqueous vapour over 1 in 2 potash at 18°, 7·7 mm.; whence,
Weight of nitrogen ·0378 g.

Experiment IV. Combustion of the substance.
This was done in the ordinary way with lead chromate;

Weight of substance 1·4997 g.
Weight of CO_2 ·1640 g.
Weight of H_2O ·6322 g.

Experiments II., III., and IV. were all made with one crystal of the substance.

Calculation of Results.

		Percentages	
		Found	Calculated from formula proposed above
From Expt. I.	Al.	7·07	7·00
„ „ II.	S.	16·50	16·55
„ „ III.	N.	11·1	10·9
„ „ IV.	C.	2·98	3·10
	H.	4·73	4·68

The following calculation was made as a check upon the analysis:—

Percentage of guanidine, CN_3H_5 ...	15·39*	
„ „ Al_2O_3	13·32	(calculated from Expt. I.)
„ „ SO_3	41·20	(„ „ Expt. II.)
„ „ H_2O...	30·51†	
	100·42	

In order to prove that the crystals obtained were of constant composition, another sample was examined as in Experiment I.

Weight of substance ·4872 g.
Weight of Al_2O_3 ·0646 g.;
whence, Percentage of Al 7·03.

* Wt. of CN_3H_5 = (wt. of C + wt. of N) $\times \frac{CN_3H_5}{CN_3} = (2{\cdot}98 + 11{\cdot}1)\frac{59{\cdot}07}{54{\cdot}03} = 15{\cdot}39.$

† H present as H_2O = total wt. of H − wt. of H in $CN_3H_5 = 4{\cdot}73 - (15{\cdot}39 - 14{\cdot}08)$
$= 3{\cdot}42;$
$\therefore$ wt. of $H_2O = 3{\cdot}42 \times \frac{H_2O}{H_2} = 30{\cdot}51.$

This agrees satisfactorily with Experiment I. and with the calculated percentage.

As regards the preparation of the substance, the best results were obtained by the following method:—

Approximately equivalent quantities of guanidine carbonate and crystallised aluminium sulphate are dissolved, separately, in water. Dilute sulphuric acid is added drop by drop to the guanidine carbonate solution until no further effervescence occurs. The two solutions are then mixed, filtered if necessary, concentrated by boiling if the solution is not sufficiently strong, and left to evaporate in a vacuum desiccator. Large, well-developed crystals may thus be readily obtained.

A crystallographic examination of the substance was made in the Mineralogical Department of the University under the direction of Mr A. Hutchinson, to whom I am indebted for the following report:

"The crystals are short hexagonal prisms terminated by basal planes. They are of considerable size, measuring up to 10 mm. across the base, and up to 5 mm. along the axis. They exhibit a perfect basal cleavage. No faces other than those of the prism and base were observed, but on immersion for a few moments in water, beautiful etched figures were developed on the basal planes. Under the microscope these are seen to be bounded by very flat three-sided pyramids on an equilateral triangular base, one edge of which is parallel to a prism edge. The triangular markings on the two parallel basal planes point opposite ways and the planes bounding them are parallel. From this it may be concluded that the crystals probably belong to the scalenohedral class of the rhombohedral system.

Sp. gr. 1·806 at $13\frac{1}{2}^{\circ}$ compared with water at 4°.

Examined in convergent polarised light, the characteristic uniaxial interference figure is seen through the base. Birefringence, fairly strong, negative. The indices of refraction for sodium light, determined by the minimum deviation method, using two natural prism faces, are as follows:

$$\mu_o = 1{\cdot}5423, \quad \mu_e = 1{\cdot}4540."$$

I hope at a later date to attempt a further examination of the formation of double salts of guanidine and its derivatives, and in particular to try whether they will not, under suitable conditions, form vitriols and alums.

Guanidine sulphate crystallises with half a molecule of water (Matignon, *Compt. Rend.* 1892, 114, 1432), and aluminium sulphate ordinarily with eighteen molecules. Thus the total amount of water of crystallisation contained in the two sulphates, separately, is greater than that contained in the double sulphate here

described, and less than the amount that would be required for the formation of an alum. It follows that there is, not improbably, a transition temperature above which the double sulphate with twelve molecules of water is stable, and below which it cannot be obtained by simple evaporation of a solution of the mixed salts.

Conversely, the hypothetical alum should have a transition temperature below which its formation is possible. Therefore it seems not unreasonable to hope that it may be possible to isolate it by working at a sufficiently low temperature.

An attempt to prepare a vitriol containing guanidine and copper has been unsuccessful, but a double sulphate of guanidine and nickel has been obtained. Its description is however postponed until the subject has been more thoroughly investigated.

On the property of a double-six of lines, and its meaning in hypergeometry. By H. W. Richmond, M.A., King's College, Cambridge.

[*Received* 25 February 1908.]

The name Double-Six was given by Schläfli (in Vol. II. of the *Quarterly Journal of Mathematics*, p. 116) to sets of twelve lines $(a_1, a_2, a_3, a_4, a_5, a_6; b_1, b_2, b_3, b_4, b_5, b_6)$ having the property that every line of the first six intersects every line of the second six, except that which has the same suffix; a_r intersects b_s provided $r \neq s$. Such sets of lines appear in connexion with surfaces of the third order, but a double-six can be built up and the property established independently.

By interpreting the six coordinates of a line as coordinates of a point in space of five dimensions, we arrive at an interesting theorem in hypergeometry, essentially equivalent to that of the double-six, but presenting the same fact in a more significant form. When six points have been taken in space of five dimensions, and a plane (i.e. a space of four dimensions) has been determined by each set of five of the points, the six points and six planes are said to form the vertices and faces of a hexahedron. The theorem may be stated as follows:

If in space of five dimensions a quadric passes through all the vertices of a hexahedron and touches five of its faces, it must touch the sixth face also.

Let $A_1, A_2, A_3, A_4, A_5, A_6$ be the vertices of a hexahedron and let a quadric pass through these points and touch the faces opposite to A_2, A_3, A_4, A_5, A_6, the points of contact being denoted by B_2, B_3, B_4, B_5, B_6. Since A_1 is on the quadric and lies in the tangent plane at B_2, B_2 must lie in the tangent plane at A_1, and the line A_1B_2 must lie wholly on the quadric. For a system of homogeneous coordinates $(x_1, x_2, x_3, x_4, x_5, x_6)$ let the hexahedron of reference be that whose vertices are $A_1, A_2, A_3, B_4, B_5, B_6$: the equation of a quadric passing through these points and such that the tangent plane at each of the three last points contains the three first is

$$Ax_2x_3 + Bx_3x_1 + Cx_1x_2 + Dx_5x_6 + Ex_6x_4 + Fx_4x_5 = 0.$$

By the introduction of suitable real factors into the coordinates (x) this equation may be reduced to one of the forms

$$x_2x_3 + x_3x_1 + x_1x_2 = \pm (x_5x_6 + x_6x_4 + x_4x_5),$$

and it will not be necessary to work out more than one case. Let the quadric be

$$x_2x_3 + x_3x_1 + x_1x_2 = x_5x_6 + x_6x_4 + x_4x_5 \quad \ldots\ldots\ldots\ldots\ldots(1),$$

and consider now the coordinates of B_2 and B_3. The former lies in the tangent planes at A_1 and A_3, which are $x_2 + x_3 = 0$ and $x_1 + x_2 = 0$; we may take therefore the following coordinates:—

For B_2, $\quad 1, -1, 1, f, g, h,$

where by (1) $\quad gh + hf + fg + 1 = 0,$

or $\quad (f+1)(g+1)(h+1) = (f-1)(g-1)(h-1).$

For B_3, $\quad 1, 1, -1, l, m, n,$

where $\quad (l+1)(m+1)(n+1) = (l-1)(m-1)(n-1).$

The coordinates of A_4, A_5, A_6 may now be found; A_4 lies in the tangent planes of B_5, B_6, B_2 and B_3, and from these we deduce the coordinates:—

For A_4, $\quad a, f, l, -1, 1, 1.$

For A_5, $\quad b, g, m, 1, -1, 1.$

For A_6, $\quad c, h, n, 1, 1, -1,$

where $\quad (a+1)(f+1)(l+1) = (a-1)(f-1)(l-1),$

$(b+1)(g+1)(m+1) = (b-1)(g-1)(m-1),$

$(c+1)(h+1)(n+1) = (c-1)(h-1)(n-1).$

From these relations in $a, b, c, f, g, h, l, m, n$ it is clear that

$$(a+1)(b+1)(c+1) = (a-1)(b-1)((c-1),$$

or $\quad bc + ca + ab + 1 = 0.$

Hence the point B_1 whose coordinates are

$$-1, 1, 1, a, b, c$$

lies on the quadric (1), and its tangent plane passes through A_2, A_3, A_4, A_5, A_6; that is to say, the quadric touches the sixth face of the hexahedron. Q.E.D.

It is useful to construct this figure with a quadric in space of five dimensions as the starting-point. Any point A_1 may be taken on the quadric, and five points B_2, B_3, B_4, B_5, B_6 lying on the quadric and in the tangent plane at A_1 may also be taken arbitrarily; the rest of the figure may then be obtained uniquely. For of the simply infinite system of planes which contain four points B_3, B_4, B_5, B_6, two touch the quadric: one of these has A_1 for its point of contact and contains B_6; the other is therefore determinate. Five points A_2, A_3, A_4, A_5, A_6 are thus found whose tangent planes contain four of the points B_2, B_3, B_4, B_5, B_6; and these tangent planes, by the theorem proved above, will intersect in a point B_1 on the quadric. The six coordinates connected by a quadratic relation which define the twelve points

$$A_1, A_2 \ldots A_6, B_1, B_2 \ldots B_6$$

serve equally to define twelve lines in space of three dimensions; and when two points such as A_1 and B_2 lie each in the tangent plane of the other, the corresponding lines intersect. Putting this interpretation on the last result we obtain a known method of building up a double-six; viz. If a_1 be a line in space, and b_2, b_3, b_4, b_5, b_6 any five* lines meeting a_1, five further lines a_2, a_3, a_4, a_5, a_6 may be found each meeting four of the five lines b_2, b_3, b_4, b_5, b_6; and a twelfth line b_1 must exist which meets the five a_2, a_3, a_4, a_5, a_6. Clearly the formulae obtained above can be applied to prove this without mention of hypergeometry.

I have not succeeded in finding any extension or analogue of the above theorem to a geometry of other than five dimensions; it is remarkable if the theorem belongs to space of five dimensions and to no other. In conclusion, the theorem may be stated in a purely algebraic form:

If in a symmetrical determinant of six rows the six elements in the leading diagonal all vanish, and the first minors of five of these elements also vanish, the minor of the remaining element must vanish.

* No two of the five should intersect and no four should lie on a conicoid.

Report on the brain of a microcephalic idiot with bilateral porencephaly. By W. L. H. Duckworth, M.D., Sc.D., University Lecturer in Physical Anthropology.

[*Read* 27 January 1908.]

[Plate XVII.]

Among the subjects dissected in the Anatomy School at Cambridge, during the Lent Term 1905, was a microcephalic male individual of small stature (Subject No. 11).

The skull-cap and the encephalon were made over to me for examination, the results of which are given in the sequel.

Through the courtesy of the Superintendent of the Three Counties Asylum, I am able to provide the accompanying clinical notes on the case.

EXTRACTS FROM CASE BOOK No. 1.

William Sharman. *Admitted from St Neots Union, March* 8, 1865. *Age* 18. *Single. No occupation.*

He is not very well nourished, has the general appearance of an idiot. Eyes dark and clear. Head small and very flat behind, expression of countenance idiotic. He does not appear to have any disease of the lungs or heart. He has been an idiot from birth, has very imperfect articulation. His understanding is slight although he partially comprehends when spoken to. He does not appear dirty in his habits. He has been taken care of in St Neots Union House up to the time he came here, but latterly he became violent and destructive so they could not manage him. He is not epileptic and does not appear to be paralysed.

May, 1878.	Fairly good health, idiotic, speechless.
June 5 „	Is suffering from an inflamed testicle retained in inguinal canal, tender and painful, poultice, bed. H. M.
March 23, 1882.	Bodily condition fairly good, very little mind, cannot answer the simplest question. Has bubonocele of right side, and right testicle occasionally gets caught in right inguinal canal.
December 2, 1882.	Does not speak, quite idiotic, cannot employ himself, feeble health, very destructive.
May 6, 1885.	Has a "bubonocele," mind feeble, never speaks, in feeble health and condition.
October 15, 1888.	Has no mind, smiles blandly at nothing, suffers at times from an inguinal hernia which becomes strangulated; unclean and very destructive.
1895.	Several years' entries are intentionally omitted as nothing new could be stated in the patient's condition. Hernia had not descended for many months.
1896.	No change.
1897.	No change.

1898.	No change.
1899.	Confined to bed with hernia, in other respects no change.
1900.	No mental or bodily change, destructive and dirty in habits.
1901.	No change as above, never speaks nor takes any apparent interest in anything except his food.
1902.	Again confined to bed with hernia. No mental change. Unclean and destructive.
1903.	Frequently confined to bed with hernia.
January, 1904.	No mental change, confined to bed with hernia for some months, habits faulty and destructive.
October 17, 1904.	Ordered to bed, weak and very unclean in habits.
„ 25 „	Very much weaker, still confined to bed, losing flesh and unclean.
November 4 „	Patient died this morning.

Powers of Sight—Indifferent.
„ Hearing—Indifferent.
Taste and Habits—Ravenous in eating, would eat grass or rubbish, appeared timid and frightened, would stand in a corner for hours if not encouraged to sit down or walk about.
Speech—Never carried on conversation, but could mutter a few words unintelligibly.

The calvaria measures 154 mm. in extreme length, and its extreme breadth is 120 mm. The corresponding endocranial dimensions are 137 mm. and 103 mm. The several cranial components are completely fused endocranially, though externally the coronal and lambdoid sutures are quite distinct. The sagittal suture has disappeared from both aspects of the skull-cap.

The cranial vault is thick, but there is comparatively little variation in thickness in the different regions. Thus though somewhat reduced in thickness above the pterion, the usual marked contrast in this respect, between this region and the parietal area, is not found here.

The calvaria is asymmetrical, and as the inspection of the cerebrum suggests, the left half is more capacious than the right. The capacity of the right half is further reduced by a thickened endocranial ridge, corresponding in position to the external occipital protuberance; this ridge, although formerly median in position, has encroached very considerably on the right side. Just behind the vertex, the internal aspect of the calvaria is characterised by a scarred and roughened surface. Behind this area again and to the right of the superior longitudinal sinus, a depression is seen and this corresponds to and is probably the result of a large haemorrhagic tumour which has destroyed most of the right occipital lobe of the cerebrum.

The foregoing characters are the most striking features of the calvaria.

The Encephalon. (Figs. 1—7 incl.)

General and Surface Anatomy.

The general characters of the encephalon are foreshadowed by those of the calvaria. The cerebrum is microcephalic and asymmetrical: though the cerebellum, while smaller than usual, is not in this respect, so anomalous as the cerebrum. The latter (when first removed from the skull) weighed only 550 gm.

In length, the right hemisphere measures 122 mm., the corresponding dimension of the left hemisphere being 128 mm. But a prolonged sojourn in alcohol has caused shrinkage, so that the dimensions of cerebrum and calvaria no longer correspond (cf. the endocranial measurements). The cerebral width is now also less than that of the endocranium, and measures 91 mm. only, of which the right hemisphere provides 45 mm., and the left hemisphere 46 mm. In maximum height, the right hemisphere measures 75 mm., the left measuring 79 mm. The latter hemisphere is thus the larger in each diameter.

The proportions of the hemispheres, before and behind the corpus callosum, may be exhibited in the following way:

	Anterior to corpus callosum	Corpus callosum	Posterior to corpus callosum	Total
Right hemisphere	31 (25·6%)	53·5 (44·2%)	36·5 (30·2%)	122
Left hemisphere	33 (25·8%)	52[1] (40·6%)	43·5 (33·6%)	128·5

The comparison of these results with the data provided by Cunningham and Telford-Smith in their descriptions of microcephalic brains (*Scientific Transactions of the Royal Dublin Society*, Vol. v. Series II.) reveals the character common to such cerebra, viz. reduction of the occipital lobe. But in the present specimen not only reduction in proportions, but also destruction of substance had occurred in the right hemisphere, as will be described presently.

The corpus callosum is well shewn in section in each half of the cerebrum, and at once attracts attention through the remarkable attenuation of the splenial end. This character will be dealt with further in a later connexion.

The sulci and gyri are simple and uncomplicated. On a first inspection it can be seen that the insula was exposed in each hemisphere. The temporal lobes are remarkably deficient in normal sulci, though shallow grooves occur, and lend a puckered or rugose appearance to the cortex of this region in both hemispheres.

[1] Owing to distortion and shrinkage since the cerebrum was divided.

Finally, the whole of the region commonly occupied by the hinder parts of the right intraparietal sulcus has been depressed and almost destroyed by a large encysted haemorrhage from a cortical vessel. The haemorrhage occupies the area supplied by those branches of the middle cerebral artery designated Nos. III. and IV. by Professor Monakow[1].

The right hemisphere (Plate XVII, Figs. 1 A, 2 A, 3, 4, 5).

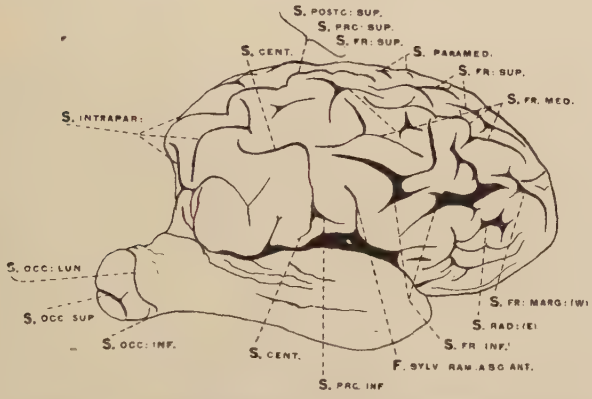


Fig. 4. The lateral aspect of the right hemisphere of the microcephalic brain ($\times \frac{1}{2}$).

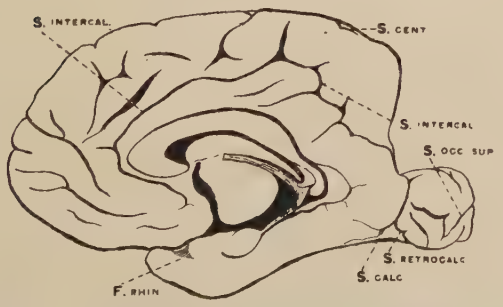


Fig. 5. The mesial aspect of the right hemisphere of the microcephalic brain ($\times \frac{1}{2}$).

The condition, and even the presence of the olfactory nerves could not be definitely ascertained owing to damage sustained by the brain during removal, but the olfactory roots were detected on both sides.

[1] *Gehirnpathologie*, 1897, S. 673.

The optic nerves, chiasma, and tracts are present but small. The external geniculate body is absent from the right hemisphere, or atrophied so far as to be unrecognisable: in the left hemisphere the external geniculate body is much smaller than usual, though still distinct.

No obviously abnormal conditions were found in the remaining cranial nerves.

The surface anatomy of the cerebral gyri and sulci will be discussed in the following paragraphs.

Central region.

The Sylvian fissure is present and does not differ markedly from the normal type as regards its posterior limb. (It must be mentioned that a distinct gyrus separates the hinder end of this fissure from that part of the cortex which has been involved in the haemorrhagic effusion. Therefore the middle cerebral artery was probably not involved in this part of its course. More probably one of the end-branches, lying on the cortical surface and given off after the emergence of the terminal trunks from the depths of the Sylvian fissure, was ruptured.)

The temporal operculum is well-developed. But though the orbital operculum is normal, the parietal (now in part destroyed) and the frontal opercula were defective in development and did not extend sufficiently far over the insula to conceal it. The insula is thus exposed, but the nature of this exposure is such that it cannot be compared with that in apes. In the latter, the frontal operculum is small and the orbital operculum practically non-existent. Here both frontal and orbital opercula are distinct although the former is not fully developed. Hence the condition is a retention of that normally attained at the termination of the eighth month of intra-uterine existence.

The fissure of Sylvius sends off one orbital branch, which however does not cut quite through the operculum. It probably represents the inner of the two usual sulci in this position. Another sulcus given off from the Sylvian fissure and cutting through the opercular lip to separate frontal and orbital opercula, is identified with the anterior ascending limb of the fissure of Sylvius. This identification is open to criticism, for the sulcus is directed obliquely backwards and upwards and the frontal operculum bounded by it is of unusually great width.

Much difficulty is found in identifying the central sulcus. My interpretation is that this sulcus is not continuous throughout its length. And I believe that upper and lower components can be recognised, while between the two the cortex is marked by sulci directed in the long axis of the hemisphere. The furrow thus regarded as the lower part of the central sulcus is however

compounded of two sulci which diverge as they approach the margin of the operculum. Of these two, the posterior is the lower part of the central sulcus and the anterior seems to represent the inferior precentral sulcus.

Between the upper and lower central sulci, others are seen (as already described) in the long axis of the hemisphere. Of these, the uppermost may be regarded as a combination of the upper postcentral and precentral elements with part of the superior frontal sulcus. The latter is further represented by two detached sulci situated further forwards and between these and the upper cerebral margin are dimples representing a marginal frontal sulcus.

A middle precentral sulcus and three detached portions of the middle frontal sulcus are identified and to the latter, two more small sulci (representing Wernicke's sulcus fronto-marginalis) are accessory.

The sulcus frontalis inferior seems to be replaced by two detached sulci and below the more anterior of these another fronto-marginal sulcus (Eberstaller's) may be seen. The orbital sulci require no special description.

In the parietal region the disturbance brought about by the haemorrhagic effusion has much complicated the arraugement of sulci. The sulcus intraparietalis is replaced by several independent sulci as represented in Fig. 1. Finally other sulci can be respectively identified with the sulcus occipitalis superior and the sulcus occipitalis lunatus.

Temporal region.

This is the most remarkable part of the cortex: from the Sylvian fissure right round to the hippocampal fissure on the mesial aspect, no true sulcus is found. Immediately below the Sylvian fissure are four or five slight furrows, the direction of which is nearly parallel to the first-named fissure but they are the merest wrinkles on the cortical surface. The cortex itself is attenuated and the lateral ventricle seems to have been much dilated owing to blood having been effused into its cavity.

The mesial aspect.

This aspect presents some very noteworthy features.

I. (*a*) The commissures. It is uncertain whether the anterior commissure was present. It is certainly not large or prominent, but as in the process of injecting the brain this region has been much disturbed, the anterior commissure may possibly have been destroyed.

(*b*) The corpus callosum has a genu and rostrum of similar form to those of the normal brain, except that the rostrum is rather thicker than usual. The abnormality of the corpus callosum consists in the extraordinary attenuation of the splenium and adjacent portion of the commissure (cf. Fig. 18). The gyrus of Retzius is therefore fully exposed, and the attenuation is doubtless due to the absence of interoccipital (visual), interparietal, and intertemporal fibres which should cross in this region.

(*c*) The psalterium on the other hand is not reduced and the body of the fornix is rather thicker than usual: the corpora mammillaria seem to have been present, but the anterior pillars of the fornix have been destroyed in the process of injecting the brain.

II. The uncus is normally developed. But the incisura temporalis is absent. The fimbria is normal and continuous as usual with the fornix. The fascia dentata is prominent and rises boldly to the surface behind the splenium to expand into the gyrus of Retzius (Balkenwindung). Thick striae of Lancisi are seen above the corpus callosum, and below the genu (anteriorly) fuse with part of the gyrus fornicatus to form a very definite gyrus subcallosus.

III. Other gyri and sulci. The chief feature of interest is the remarkable sulcus splenialis[1] (Krueg) which, as in the lower Eutheria, forms a continuous furrow traceable from below the rostrum corporis callosi to a point just behind and rather below the splenium and gyrus of Retzius. Thence a short sulcus retrocalcarinus leads backwards to end apparently in the sulcus occipitalis inferior. But the true (and original) stem of the calcarine is rudimentary. In this respect the right hemisphere is absolutely different from the left. Two genual sulci are present and two or three smaller sulci indent the marginal gyrus.

The left hemisphere (Plate XVII, Figs. 1 B, 2 B, 6, 7).

The left is altogether larger than the right hemisphere, but is nevertheless much below the normal size. The anterior part of the temporal lobe is abnormal in respect of convolutions.

The Sylvian fissure presents no anomalous features, save that the frontal and temporal opercula are not quite fully developed. (Some reserve must be made here since the brain was much damaged in this region during the process of injection.) The insula is thereby exposed in its posterior part, not anteriorly as in apes.

Two orbital limbs, in addition to the anterior horizontal and ascending limbs can be seen. There is a sulcus subcentralis

[1] Intercalaris.

anterior continued into an inferior precentral sulcus; and a posterior subcentral sulcus runs upwards from the posterior limb of the Sylvian fissure.

The central sulcus is present, but apparently very far from the anterior end of the hemisphere. The lack of development of the parietal and occipital lobes perhaps accounts for this appearance. The sulcus passes on to the mesial aspect of the hemisphere above.

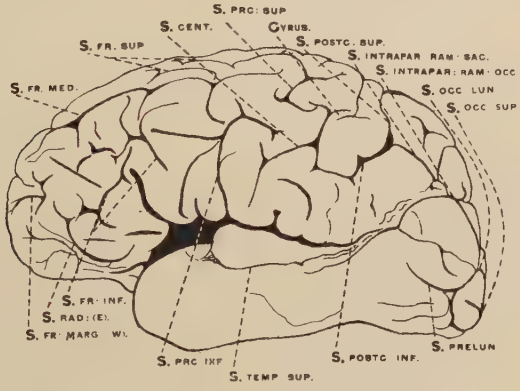


Fig. 6. The lateral aspect of the left hemisphere of the microcephalic brain ($\times \frac{1}{2}$).

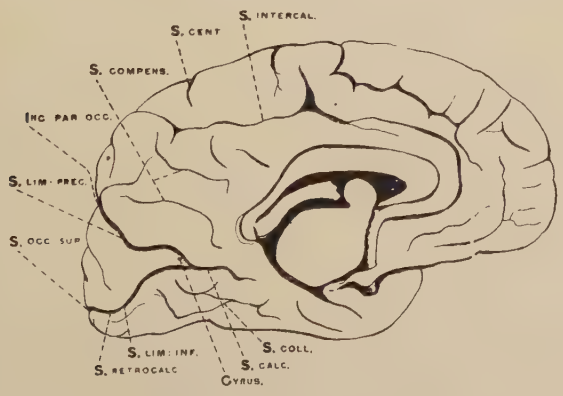


Fig. 7. The mesial aspect of the left hemisphere of the microcephalic brain ($\times \frac{1}{2}$).

The frontal lobe bears all the sulci usually present. The sulcus with radiating branches which is identified with part of the inferior frontal sulcus is a striking feature and produces a resemblance to the appearances of the corresponding region in the brain of Simia (Orang-utan).

The parietal region.

The absolutely small size of this part of the brain is shewn by a study of the following dimensions of this hemisphere. Marginal circumferential measurements of the left hemisphere along the supero-mesial border:

(*a*) from anterior to posterior pole of the hemisphere, 183 mm.

(*b*) from anterior pole to upper end of central sulcus, 120 mm.

(*c*) the same expressed as a percentage of (*a*), 65·57 mm.

(*d*) from the upper end of the central sulcus to the upper end of the paracalcarine sulcus, 40 mm.

(*e*) the same expressed as a percentage of (*a*), 21·86 mm.

(*f*) the remaining portion of the arc (*a*) (by difference), 23 mm.

(*g*) the same expressed as a percentage of (*a*), 12·57 mm.

The following table exhibits these values together with those provided by Cunningham and Telford-Smith[1] for normal and for microcephalic human cerebra.

Length of the supero-mesial border of the hemisphere = 100

	Frontal index	Parietal index	Occipital index
Normal human brains[1] ....53·3		25·5	21·2
Brain of microcephalic[1] idiot Fred (left hemisphere) ...65·5		21·5	13·0
Brain of microcephalic idiot here described (left hem.) 65·57		21·86	12·57

From this, the close resemblance between the two microcephalic cerebra, and the contrast they provide with the normal human cerebrum, will be evident.

The two postcentral components of the sulcus intraparietalis are conjoined. Halfway along this sulcus a branch springs off to be directed backwards and divides into three portions, all of which are continued backwards, the uppermost being inclined directly upwards rather than backwards. The posterior limb of the Sylvian fissure just fails to enter this complex at the point of divergence of the three terminal branches. The parietal lobe thus possesses a posterior ascending gyrus; while the notorious "pli de passage" is not recognisable. The anterior or ascending part of the supramarginal gyrus is very broad below, but is quickly reduced in width on turning backwards.

The occipital region.

The extreme posterior end of the well-marked retrocalcarine sulcus is received within the concavity of a small lunate sulcus

[1] From D. J. Cunningham and T. Telford-Smith, *Scient. Trans. Royal Dublin Society*, Vol. v. Series II. p. 299.

on the lateral aspect of the occipital lobe: the retrocalcarine is thus continuous with the superior occipital sulcus. The inferior occipital sulcus cannot be identified with certainty. The cuneus is small, but the paracalcarine sulcus can be recognised. The incisura parieto-occipitalis is distinct, but the sulcus limitans precunei is quite rudimentary.

The temporal region.

As has been already remarked, the lateral convex surface of the temporal lobe is only imperfectly convoluted. A mere groove deepening to a furrow behind, represents the first temporal sulcus, which joins the posterior limb of the fissure of Sylvius.

On the inferior surface, no incisura temporalis remains. A shallow abnormal sulcus crosses the lobe obliquely from the interior outwards about 20 mm. from the temporal pole. Further back two sulci converge and unite to form a representative of part of the collateral sulcus. There is no connection with the calcarine sulcus.

The uncus is present, but small.

The mesial aspect.

The corpus callosum, fornix and uncus are not different from those of the right side, which have already been described (see under right hemisphere). But the fascia dentata does not come so clearly to the surface as on the right side. The longitudinal striae are unusually thick, but the little gyrus of Retzius is not so evident as it is in the right hemisphere.

The optic chiasma remains attached to this (the left) hemisphere, and the optic nerves are seen to be unusually small. The left nerve is moreover distinctly smaller than the right. These facts are correlated with the defective cortical development, and here it may be mentioned that the left anterior corpus quadrigeminum is defective or at least smaller than the right.

There is a long intercalary sulcus, in front of which are two genual sulci, while the intercalary sulcus is itself continuous with the rostral sulcus, limiting a broad gyrus subcallosus. Posteriorly, there are two compensatory sulci; they are practically linear, almost parallel in direction and run obliquely upwards and backwards from near the splenium corporis callosi.

Sectional Anatomy of the Cerebrum (Figs. 8, 9, 10).

The right hemisphere was divided in the coronal transverse planes corresponding respectively to $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ of its maximum

length measured from the frontal pole to the occipital extremity. The following notes were made.

The first section (Fig. 8) passed just in front of the genu of the corpus callosum, and of the extreme tip of the temporal lobe. The sectional area is abnormally small. The lateral ventricle is not opened. The nucleus lenticularis is seen. The cortical grey matter varies in depth from 2 mm. to 1·4 mm., the thinner cortex being found on the orbital surface of the frontal lobe. Besides the small sectional extent and the attenuation of the cortical layer of grey matter, no abnormal appearances (such as heterotopia) are observed.

Fig. 8.

Fig. 9.

Fig. 10.

Figs. 8, 9, 10 ($\times \frac{1}{2}$). The anterior surfaces of coronal sections of the right hemisphere. Fig. 8. The section passed just in front of the temporal pole. Fig. 9. The section is through the mid-point of the length of the brain measured from the frontal to the occipital pole. Fig. 10. Section at three-quarters of the distance between the frontal and occipital poles.

The second section (Fig. 9) divided the hemisphere into anterior and posterior halves. The total sectional area is abnormally small. The anterior end of the descending cornu of the lateral ventricle is seen to be widely distended and it contains coagulated blood. Beneath this region the cortex is microgyrous. The cortical grey matter is thicker than in the preceding section and attains a depth of 3·7 mm. in the superior frontal gyrus. The grey matter of the optic thalamus, nucleus caudatus and nucleus lenticularis is quite distinct and these masses present the normal relations to each other and to the corpus callosum (here cut across transversely), except that the uppermost part of the lateral ventricle being dilated forms a space between the corpus callosum and the nucleus caudatus together with the optic thalamus. Further details could not be recorded owing to the imperfection of the central part of the section.

The third section (Fig. 10) passes immediately in front of the depressed area of the cortex of the occipital lobe, and behind

the corpus callosum. The total area of the section is abnormally small. The descending and posterior cornua of the lateral ventricle are filled with blood clot which appears to be of recent formation. The cortex on the inferior (tentorial) aspect of the section is not convoluted. On the lateral aspect the posterior end of the first temporal gyrus is seen to be greatly attenuated. The grey cortical matter varies in depth from 3·1 mm. on the lateral convexity (parietal region) to ·9 mm., the latter measurement being derived from the cortex of the first temporal gyrus. Cortex of intermediate thickness (1·2 mm.) is found on the lateral convexity and on the tentorial aspect.

The cerebellum.

This, like the cerebrum, is shrunken, owing to the action of the alcohol in which the brain has been immersed. The maximum transverse diameter (81 mm.) is less than that of normal cerebella. No marked asymmetry between the two hemispheres is noticed.

The flocculi are imperfect, having been damaged in the removal of the encephalon from the skull. There is no appearance indicative of any divergence in size from the corresponding organs in normal brains. The distinction of flocculus and paraflocculus is not evident. A sagittal section through the vermis reveals the fissura prima and the fissura secunda as in the normal cerebellum.

The mid-brain (Fig. 11).

Fig. 11. The thick line is a tracing of the mid-brain of the microcephalic subject. The larger area with the finer contour-line is from a normal brain, shewing the greater size in the latter case (×2 diam.).

In section, this part of the brain is seen to be very distinctly smaller than normal. The left posterior corpus quadrigeminum is smaller than the corresponding part on the right side. In a case of congenital absence of the optic nerves, tracts and external geniculate bodies, Dr Spiller found no alterations in the anterior corpora quadrigemina (*Brain*, 1901, Vol. 24, p. 632). The right crus is here distinctly smaller than the left. The external geniculate body on the right side (that on which the extensive occipital haemorrhage has occurred) is practically non-existent and the left external geniculate body is abnormally small.

The hind-brain (Figs. 12 and 13).

Fig. 12.

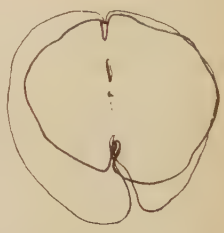


Fig. 13.

Fig. 12. Sections through the medulla oblongata in the pyramidal region. The microcephalic specimen provided a section traced with a thick line. The finer line is from a section of a normal medulla oblongata (× 2 diam.).

Fig. 13. Tracings (× 2) of sections through the decussation of the pyramids. The thick line denotes the section of the bulb of the microcephalic subject: the fine line is from a normal section.

Transverse sections were made at two levels, viz. (1) near the mid-point of the inferior olivary eminences, and (2) through the lower parts of the pyramids just above their decussation.

The sections are represented in Figs. 12 and 13, and tracings of the corresponding outlines of normal sections have been drawn in for comparative purposes.

If the section through the inferior olivary bodies (Fig. 12) is examined, this point (of inferiority in sectional area) is the first to arrest attention. The position of the dorsal parts of the inferior olives is indicated and the "control" section shews that the reduction in the microcephalic individual is to be referred chiefly to the pyramidal portions of the medulla, that which lies ventrally to the inferior olives. The lack of symmetry, although marked in the mid-brain sections and again in the lowest section through the bulb, is here not so striking.

In the section through the lowest part of the bulb (Fig. 13)

the asymmetry at once arrests attention. The inferior olivary body of the left side is rather smaller than that on the right side.

The right half of the bulb is evidently much attenuated as compared with the left half: and while all parts are thus affected, the pyramidal tract of the right side appears to be particularly reduced in sectional area. It is perhaps noteworthy that a slight but distinct degree of bilateral asymmetry is seen in the control section.

Histological observations.

For microscopic examination, portions were taken from thirteen different regions of the encephalon, and the internal carotid artery of the left side was cut in transverse section. The regions examined in this way are given in the following list.

1. The right temporal region where the dilatation of the right lateral ventricle is greatest and where the wall of the ventricle is greatly attenuated on the lateral aspect.
2. The right precuneus.
3. The right ascending frontal gyrus (i.e. the gyrus identified as such).
4. The right hippocampus with the gyrus dentatus.
5. The left first temporal gyrus.
6. The cortex of the cerebellum.
7. The splenium corporis callosi and the fornix.
8. The extreme end of the right occipital lobe.
9. The region of the forceps major in the left hemisphere.
10. The right crus cerebri and right optic tract.
11. The lowest part of the mid-brain at the commencement of the pons varolii.
12. The bulb: at the upper end of the inferior olivary body.
13. The bulb: just below the inferior olivary body.
14. The internal carotid artery.

In the following paragraphs the chief appearances presented by sections from these regions are briefly described.

1. The right temporal region.

The section passes in a vertical plane transversely to the long axis of the hemisphere, and cuts through the infero-lateral border. Owing to the dilatation of the lateral ventricle, the wall of the hemisphere is extremely attenuated, and does not exceed 3 mm. in thickness. The following features were observed.

(*a*) The whole tissue is infiltrated with innumerable droplets of amyloid substance. The droplets are especially numerous in the intermediate portions of the section, less plentiful on the ventricular aspect, and least so towards the external or superficial aspect.

These droplets are conspicuous in the great majority of the sections to be described (cf. list of specimens 1—13) and are evidently widely distributed throughout the cerebral tissues. In the mid-brain and bulb they are less plentiful, but they are seen in the cerebellum (cf. *infra*). In sections stained with methyl violet the droplets assume a slightly pink coloration and hereby their "amyloid" nature is held to be indicated. The characteristic iodine reaction could not be obtained however. In sections stained with thionin, the droplets are stained blue: among them are seen some much smaller masses, stained distinctly pink: the latter (smaller) masses are therefore judged to be mucoid, the larger more conspicuous droplets failing to give the characteristic pink mucin indication with thionin. In sections stained with Grubler's haemalum and acid fuchsin after van Gieson's method, very striking results follow. Near the surface of the cortex are many violet-stained, and therefore "amyloid" globules: but deeper down, and near the ventricular aspect (of the attenuated hemisphere-wall) brilliant red masses are found: they are less abundant than the violet-stained globules. These histological results indicate that both amyloid and colloid substances are present in the cortex of this region: while the thionin test reveals the presence of mucin or some closely-allied body: all these substances are independent of nerve-cells and cortical vessels, so far as can be observed. As the droplets which give the reactions of amyloid tissue are by far the most plentiful, the globules or droplets will be described as amyloid in the following paragraphs: but this does not exclude the presence of colloid substance and free mucin in the sections.

Such droplets are present in abundance in many types of degenerate nerve-tissue. Their mode of origin seems to be still obscure. They are not, however, absolutely diagnostic of a diseased condition of the nerve-tissue, for I found a certain number in sections of a normal human brain which I employed as a "control" in connexion with the present case. In spite of this, their abundance at any rate can be claimed as indicative of some pathological condition. (It remains to add that the "control" brain just mentioned had been preserved in alcohol for a number of years. It seems not improbable, moreover, that these drops are precipitated by the fixing or preservative reagent, in a fluid which during life percolated the more solid constituents of the cerebral substance.) The appearances presented by the sections of Block 12 (the bulb) point almost conclusively to the derivation of these globules from the substance of nerve-cells.

(*b*) The distinction between grey matter and white matter can be still recognised. The white matter is especially attenuated.

In sections stained by Weigert's method, three chief zones can

be distinguished in the thickness of the ventricular wall, viz. an inner zone abutting on the ventricular cavity. This zone is poor in fibres and such as are stained are fine, wavy and short. Amyloid droplets and many deeply-stained nuclei of varying size are present. Next to this zone comes a second layer in which tangentially-directed bands of fine and slightly-varicose fibrils can be seen. As the section is followed peripherally (i.e. towards the exterior), the tangential arrangement of fibrils gives place to an irregular network in the meshes of which are crowds of amyloid masses. Still nearer the surface is a zone in which nerve-cells occur. These are not numerous nor can the usual types be distinguished. Nerve-fibrils are still seen, but are less plentiful and the amyloid droplets are also more scanty here. Many small deeply stained nuclei occur. No definite marginal zone of tangential nerve-fibrils can be seen, but amyloid masses are found on the surface.

The acid fuchsin stain (with methylene blue) shews a few nerve-cells of which the nuclei alone are distinct. The capillary vessels are perhaps slightly distended, but no definite evidence of degenerative change was obtained.

2. The precuneus and adjacent part of the depressed cortical area.

In these sections, part of the superficial blood-clot is shewn. Where this rests on the depressed cortex, the margin of the latter is fringed with numbers of amyloid droplets. The effects of the pressure exercised by the clot upon one of the gyri bounded by the compensatory sulcus, are definitely shewn. The gyrus is narrowed, so as to project towards the mesial aspect as a narrow opercular lip, sickle-shaped in section. The upper surface of the gyrus has been exposed to pressure exercised by the clot, and in it the normal cortical structures are unrecognisable. The lower surface of the gyrus preserves traces of the distinction of cortex and white matter. The latter contains amyloid masses. The cortex itself is not extremely modified, though the pia mater covering it is thickened and contains many droplets.

3. The gyrus identified as the anterior precentral.

The cortex is covered by a thick layer of felted fibres. The pyramidal cells are somewhat shrunken; more important is the fact that their nuclei do not take up staining reagents well, while the cell-substance contains many granules staining deeply with acid fuchsin.

4. The hippocampus major, gyrus dentatus, and fimbria (Fig. 14).

These sections present few or no important changes. The amyloid droplets occur in the fimbria. The substantia reticularis alba (Arnold) presents a felted appearance. The hippocampal structures are not shrunken, as may be seen by comparing a

tracing of the section with corresponding drawings made from the control specimens (Figs. 14, 15, 16, 17).

Fig. 14.

Fig. 15.

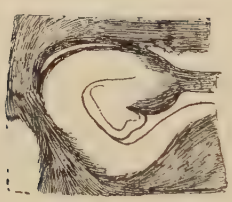


Fig. 16.

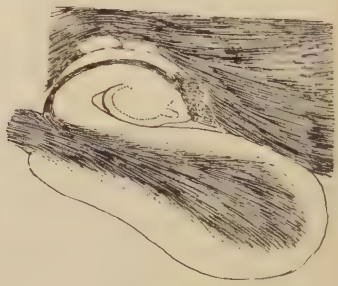


Fig. 17.

Figs. 14, 15, 16, 17 ($\times 2$). Sections through the hippocampus major, fimbria, and gyrus dentatus. Fig. 14. The microcephalic brain. Fig. 15. From a case of epilepsy. Figs. 16 and 17. From normal brains used as "controls."

5. First temporal gyrus of the left cerebral hemisphere.

In these sections, cortex and white matter are clearly distinct. The characteristic feature is a broad band of tangentially-directed fibres situated in the grey matter. This band represents the line of Baillarger. Sections stained by Weigert's method reveal numerous fine medullated fibres quite as distinctly as do the control specimens from a normal brain. But in the cortex of the microcephalic individual the matrix is studded with innumerable granules and droplets. Otherwise no striking aberration was detected.

6. The cerebellum.

The several zones are distinct. Purkinje's cells are not abnormal in appearance. The amyloid droplets occur rather plentifully among the medullated fibres running in the axes of

the folia. The molecular and nuclear layers call for no special description.

7. The splenium of the corpus callosum with the adjacent structures (Fig. 18).

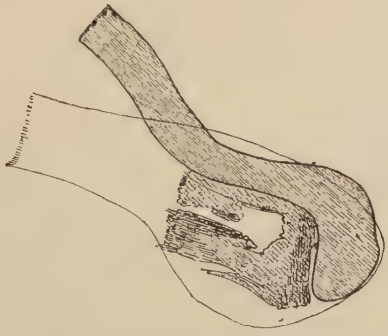


Fig. 18. Tracings through the splenium corporis callosi. The shaded area denotes the splenium in the microcephalic brain. The fainter line is from a tracing of a normal corpus callosum ($\times 2$).

The splenium is absolutely much smaller than in the normal brain. The body of the splenium consists of transversely-directed fibres among which no patches of degeneration can be seen in Weigert preparations. But upon the upper aspect is a band of degenerated tissue with multitudes of oily-looking droplets. This zone contains a certain number of longitudinal fibres, no doubt belonging to the longitudinal striae. Again on the lower surface of the corpus callosum is another broad zone of degenerate tissue with characters similar to those observed in the upper zone just described. The fornix is thickened and (probably in consequence of the attenuation of the splenium) is not so closely applied to the corpus callosum as usual.

8. The extreme end of the right occipital lobe. The sections are in the horizontal plane.

Cortex and white matter can be distinguished. But important modifications are evident. The tangentially-directed stria of Gennari is not present, and this is of especial interest in view of the absence of the external geniculate body. The corresponding cortex of the left hemisphere contains a stria of Gennari visible macroscopically. The cortex of the cuneus immediately superior to the retro-calcarine sulcus is greatly deficient in nerve-cells, while it is absolutely crowded with the hyaline drops so often mentioned in the preceding notes. They seem particularly numerous beneath the pia mater upon the superior lip of the sulcus.

9. Forceps major of the corpus callosum in the left hemisphere.

With such extensive destruction of the right parieto-occipital area, with such marked modification of the temporal lobes and attenuation of the splenium, it is a subject of interest to enquire whether the commissural fibres connecting one hemisphere with the other (through the forceps major of the corpus callosum) are degenerate. Weigert preparations shew no such bands of degenerated fibres.

The gyrus dentatus appears in these sections and contains cells with no signs of degeneracy. The prominence of the gyrus dentatus in this specimen is due to the small size of the splenium.

10. The mid-brain and optic tract on the right side.

The optic tract appears in the lower part of the section and again in the upper part of its course. In both regions patches of degenerated tissue occur. The absence of the external corpus geniculatum on this (the right) side has been mentioned already. Upon the free surface of the anterior corpus quadrigeminum, inflammatory change is evident: numerous cells have apparently invaded the brain-tissue and amyloid masses are numerous. On the other hand, the more centrally-situated parts, e.g. the red nucleus, present little or no change.

11. The posterior corpora quadrigemina and the upper part of the pons.

The sectional area is markedly smaller than the normal (cf. Fig. 11). The section is asymmetrical, for the right crus and the left posterior corpus quadrigeminum are distinctly smaller than the corresponding parts on the opposite sides. But Weigert preparations shew no actual patches of degeneration, the only difference observed being a paucity of fibre and cell-elements in the left posterior corpus quadrigeminum. The pyramidal tracts in particular, while differing greatly in actual sectional area, shew no degenerated parts. Upon the upper aspect of the corpora quadrigemina evidence of inflammatory processes (similar to those described in connexion with section 10) is observed.

12. The bulb: in the region of the inferior olive (Fig. 12).

No tracts of degenerated tissue occur. The right half of the section is smaller than the left. The chief points to notice are (*a*) the occurrence of inflammatory changes on the ventricular aspect of the section with commencing infiltration of the nervous tissue, and (*b*) the presence of numerous granules in the cell-substance of large cells identified as those of the nucleus of the twelfth cranial nerve. The granules in question are quite distinct from the Nissl bodies, for with acid fuchsin combined with methylene blue, both may be stained. The granules unlike the Nissl bodies acquire a bright pink tint with the mixed stain just mentioned.

the Nissl bodies being dark blue. The pink granules in some cells occupy nearly the whole of the cell-substance. In the cells of the inferior olive this replacement has reached a further stage and in some places nothing remains to shew the position of a cell save the aggregate of granules.

13. The bulb: in the region of the pyramids at the lowest part of the inferior olive (Fig. 13).

The chief feature is the asymmetry of the sections, the right pyramid being very much smaller than the left. Similar remarks (concerning the presence of abnormal granules or globules in the nerve-cells) apply to this as to the preceding section (12). Amyloid droplets are seen along the course of blood-vessels, and there is a suggestion of inflammatory change in the area immediately surrounding the central canal. In Weigert preparations no definitely degenerated areas are seen.

14. The internal carotid artery immediately below the circle of Willis.

The section shews that the vessel is thin-walled. It contrasts with the control specimen in not being contorted through the action of the fixing reagent; in the control specimen the arterial wall is thrown into folds owing to the contraction of the connective tissue coating. (As a "control," the internal carotid of a robust adult Hindu convict hanged for murder, was used.)

In the artery of the microcephalic individual, the endothelial lining is indistinct, but the subendothelial layer is dense. The fenestrated membrane is distinct, but not thrown into folds, as in the "control." The tunica media is thin and consists almost entirely of circularly-disposed muscle fibres with elongated nuclei. The tunica adventitia is attenuated.

Summary and Conclusions.

The foregoing report contains such observations as I was able to make on the microcephalic brain within the time at my disposal. A few remarks may be added in concluding this account. The specimen exemplifies the conditions of microcephaly and of porencephaly combined. Of other examples on record, that described by Dr Wigglesworth in *Brain* 1901, p. 127, very closely resembles the present case. In the latter, the clinical evidence is necessarily less complete, though it is a matter of good fortune that so much clinical evidence was accessible as that which is prefixed to this report, and I must repeat my thanks to the Superintendent of the Three Counties Asylum for his aid in obtaining this.

In Dr Wigglesworth's case, the brain was microcephalic and porencephalic. The hemisphere chiefly affected was however the

left, not the right as in the present instance. And judging from the appended histological report, the minute structure of the cortex was definitely altered in Dr Wigglesworth's example.

The condition in the present case is complex. In the first place, an arrest of the normal capacity of the encephalon for development has occurred, for, as we have seen, the brain is microcephalic. And again, the quality of the tissue has been defective, so that in the course of time a cortical vessel has given way, and the escaping blood has destroyed portions of the cerebral surface.

As regards the first factor, that of deficient power of growth, the present example is not an extreme case. The literature of microcephalus abounds with instances of a more exaggerated kind. The asymmetry between the two hemispheres, and certain other parts of the central nervous system, notably the pyramidal tracts from the mid-brain downwards, is perhaps worthy of special remark, and the comparison of the sections of the mid-brain and bulb with control examples, shews that the arrest of development has affected all parts of the central nervous system which were accessible to observation. Such a condition is to be clearly distinguished from a type of microcephaly in which the arrest affects little or nothing beyond the cerebrum. And of this contrasted condition the microcephalous pig described in the preceding paper (*Camb. Phil. Soc. Proceedings*, XIV. Part V., p. 447), offers a striking example.

In the cerebrum, the neopallium has been chiefly affected and the rhinencephalon differs (macroscopically at least) but little from that of the normal individual. The difficulty in identifying the central sulcus in the right hemisphere demands special mention, but is by no means uncommon in the more pronounced cases of microcephaly.

As regards the haemorrhage and its sequels, I may repeat that it appears to me indicative of the poor quality of the blood-vessels. The left internal carotid artery presents features which support this view: indeed upon inspection with the naked eye, one would hesitate to pronounce the section that of an artery, for it resembles a vein.

The haemorrhage formed a tumour upon the right parieto-occipital area, but probably did not encroach upon the motor area of that side. The clinical evidence does not refer to the state of the limbs, nor with the comparison of the two sides, so that further comment is valueless. In view of the much smaller sectional area of the right motor tract, one would expect that there would have been at least some paresis of the left side. But no degenerating bundles have been discovered in this tract. Probably the usual number of fibres never developed.

The locality of the haemorrhage and its encroachment upon

he mesial aspect of the right occipital lobe, associated with bsence of the right external geniculate body, and with an specially attenuated left optic nerve, lead one to expect to hear of ome visual defects, but no precise information is available on this ubject. The recent appearance of the clot within the right lateral entricle (descending cornu) suggests that death was due to an ncrease of intra-cranial pressure following the perforation of the ttenuated cerebral wall and the effusion of blood into the entricular cavity of the right side.

It is important to note that Dr Wigglesworth expressly avoids n appeal to any developmental defect, as having determined the oss of cerebral substance in the case described by him: whereas he scribes the cerebral defects to obstructive vascular lesions occur- ng in intra-uterine life (*op. cit.* p. 133). In both his specimen nd mine, the porencephalic condition was, however, combined with icrocephaly. In the case I describe, the porencephalic modifica- ons and the concomitant destruction of the occipital end of the ght hemisphere, were almost certainly due to vascular lesions. he latter can also be held responsible for the curious microgyrous ondition of the cortex of the temporal lobes. It is well to bear mind the emphatic warning given by Dr A. W. Campbell *Brain*, Vol. XXVIII., 1905, p. 437), against the indiscriminate vocation of "developmental defects" as the causal factors in oducing "microgyry." In the present case it would seem obable that the vascular lesions that determined "porencephaly" so brought about the microgyrous appearances. But the micro- phalic condition affects the frontal lobes (which are not poren- phalic) and the spinal cord was also asymmetrical and "micro- yelic." These microcephalic features of the case appear to me denote a factor different from the vascular degeneration to hich allusion has just been made, and this factor I believe to be fficient power of growth.

Another brain closely resembling that which I describe, is gured in Professor Starr's *Organic Nervous Diseases* (1903, g. 220, p. 536) where it is referred to as "Ferraro's" example, ithout further reference to the original description. The case scribed by Dr Hannay (*Glasgow Medical Journal*, Vol. LXI., o. 3, March 1904) bears some resemblance in so far as the asym- etry of the hemispheres, midbrain, and bulb were concerned; t the frontal lobe of the left hemisphere was chiefly affected.

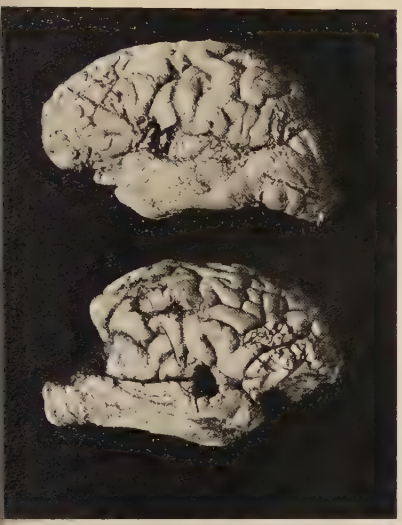
In certain features, such as asymmetry of the cerebral mispheres and of the pyramidal tracts, the Cambridge specimen esents resemblances to the case so admirably described by hroeder van der Kolk (*New Sydenham Society: Selected nographs*, 1861). In the latter instance, no abnormality of the tic nerves is recorded. In the publication to which reference

has just been made, many valuable records are preserved of earl descriptions of microcephalous and asymmetrical cerebra.

The last case to which I shall refer is that described (i a highly instructive paper) by Dr Turnbull (*Brain*, Vol. XXVII 1904, pp. 209 *et seq.*).

The brain in question presented bilateral loss of postcentra cortex, but the writer is careful to point out that the case was no one of porencephaly, but was rather due to hydrocephalus. Th attenuation of the cortex consequently produced was so extrem that the occipital ends of the hemispheres were transformed int mere thin-walled cysts. Associated therewith, Dr Turnbull foun certain conditions which he regarded as secondary to the primar changes wrought by hydrocephalic distension. These so-calle secondary changes involved the remaining cortex, the corpu callosum (splenium), and in particular the optic nerves and thei central connexions. In all these parts atrophic change was de tected, though, without desiring to criticise Dr Turnbull's con clusions, I may note that he appears to have detected marke deficiency in the number and size of fibres in various region but not definitely degenerated tracts.

While recognising the essential difference between this cas of hydrocephalus, and that of porencephalus described by mysel I have been much struck with the similarity in the parts chara terised by their diminutive size in the two brains. In both the corpus callosum (especially the splenium) was abnormall small: in both, the external geniculate bodies were either absen or of insignificant size: in both, the optic nerves were undul small. These changes Dr Turnbull attributes to the primar lesion which, in his case, is that of the postcentral cortex. Bu great as is the similarity in the parts affected, nevertheless i the example now described, I do not feel able to assign to thes changes in the splenium, external geniculate body and opt nerve, a corresponding origin, i.e. one secondary to the primar cortical lesion. In my example, the asymmetry and the micr cephalic conditions complicate the problem. And to these I pref to ascribe a common origin with the dwarfed condition of the opt nerve, &c., to which I have just referred. This common orig seems to consist in an impairment of the capacity of part of th central nervous system to attain the normal adult status.



1. The microcephalic brain. (A) Lateral aspect of the left hemisphere. (B) Lateral aspect of the right hemisphere, with depressed occipital cortex.

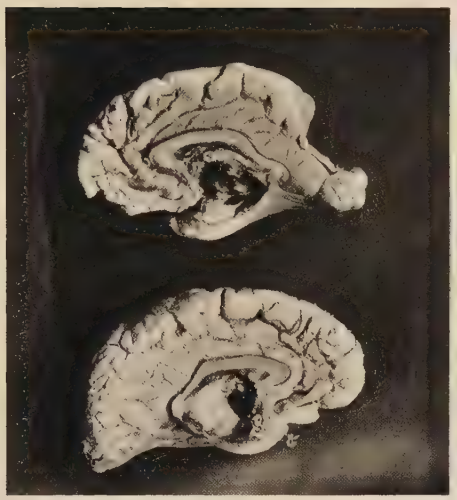


Fig. 2. The microcephalic brain. (A) The mesial aspect of the right hemisphere, with depressed occipital cortex. (B) The mesial aspect of the left hemisphere.

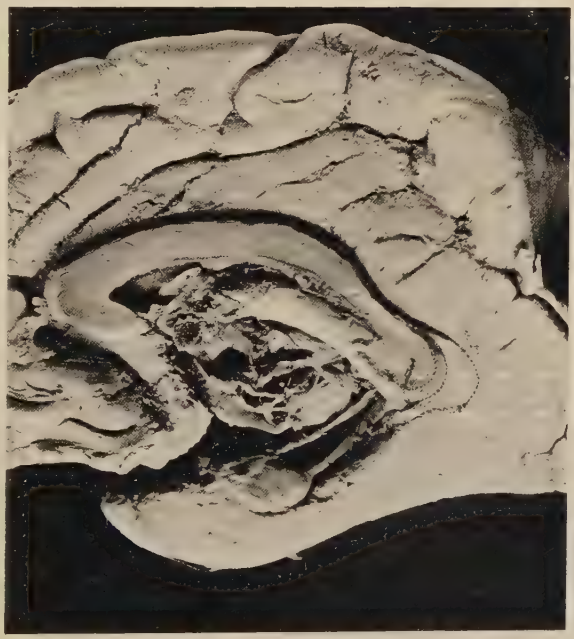


Fig. 3. The microcephalic brain. Part of the mesial aspect of the right hemisphere, to shew the attenuated splenium corporis callosi (Spl.), and the gyrus of Retzius (R).

The spectrum of the discharge from a glowing lime cathode in mercury vapour. By F. Horton, M.A., St John's College.

[*Read* 10 February 1908.]

While investigating the discharge of negative electricity from a Wehnelt cathode in various gases at different pressures, it was observed that the colour of the luminous discharge in certain gases altered as the gas pressure in the apparatus or the temperature of the cathode was varied. The experiments described in the present paper were commenced with the object of investigating the spectrum of the luminous discharge under different circumstances.

The special form of discharge tube* used is shown diagrammatically in Fig. 1. The cathode *A* is a strip of platinum foil about 2 centimetres long and 2 millimetres wide, covered with lime, or, in later experiments, with a mixture of lime and baryta. The ends of the platinum strip were welded on to two stout platinum wires through which the heating current was conducted. These were sealed through a ground glass stopper which was made air-tight by surrounding it with mercury. The anode *B* was of aluminium. The centre part of the tube was of small diameter (about 2 millimetres) and here the brilliancy of the positive column was enormously increased.

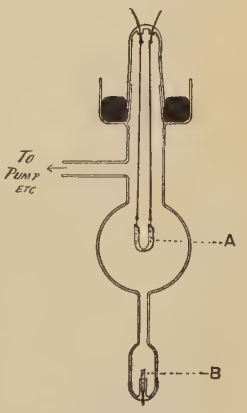


Fig. 1.

With a glowing lime cathode a luminous discharge can be obtained—at certain gas pressures—with a difference of potential of 12 or 14 volts. In the present case much larger potential differences were necessary to maintain a bright discharge on account of the constriction in the discharge tube. The difference of potential used was usually between 120 and 400 volts. The difficulty was to get the discharge to start. When once started a smaller voltage would suffice to maintain the current. For this reason the discharge was generally started with an induction coil.

Commencing with the cathode hot and the tube filled with air and gradually reducing the gas pressure in the apparatus, the

* The Author wishes to record his indebtedness to the Government Grant Committee for Scientific Investigations for the means of purchasing several of the tubes used in these experiments.

luminous discharge would appear at a pressure of a few millimetres. The spectrum showed the nitrogen bands brilliantly and also a faint mercury spectrum. On still further reducing the pressure the mercury lines increased in brightness and the nitrogen bands gradually faded away. Three new lines were then observed to show up in the orange part of the spectrum. These increased in brightness as the pressure was lowered and finally stood out sharply on a dark background. By raising the temperature of the cathode the current through the tube was increased, the orange lines became more brilliant and two new lines appeared in the red. The wave-lengths of these lines were measured by means of a direct wave-length measuring spectroscope and found to be:

6912	red
6715	
6232	orange
6121	
6070	

The current through the tube was now 30 milli-amperes and the mercury spectrum was brilliant*. No other bright lines were observed, but the hydrogen red line showed up faintly at times. The three orange lines were of about equal intensity. The red line 6715 was not quite so bright and 6912 was still fainter and was always the last to appear as the current was increased. These lines could not be found recorded in any table of wave-lengths of mercury lines, nor, so far as I could find, of lines in the spectrum of any element. At first it was thought that they might be due to calcium or barium from the cathode. There is a strong calcium line at 6122 in the solar spectrum but it is accompanied by 6103 and 6162 which Kayser and Runge regard as making up one of the calcium series of triplets. By throwing the spectrum of lithium into the field of view of the spectroscope it was shown that the red line measured as 6715 was not the lithium line 6708.

It seems therefore that the lines are due to mercury, and are produced either by the special method of causing the luminosity used in these experiments, or they are due to some new substance formed from mercury during the passage of the discharge. Experiments were therefore made to see if these lines could be obtained in the absence of mercury. For this purpose a long vertical spiral of glass tubing was inserted between the mercury pump and the discharge tube. This spiral was immersed in liquid air and the apparatus pumped down. This would effectively prevent mercury vapour coming over from the pump to the spectrum tube. At a low gas pressure it was now very difficult to get the discharge to

* The mercury spectrum referred to consisted of the lines 5790, 5770, 5461, 4916, and 4359. The orange line 6152 was only seen in the presence of helium gas.

pass. The mercury spectrum was still seen faintly and also the three orange lines. The inability to get rid of the mercury spectrum with this arrangement was probably due to the vapour combining with the aluminium anode during the former experiments. The aluminium anode was therefore replaced by a platinum disc and the whole tube carefully boiled in nitric acid to get rid of all traces of mercury. Repeating the experiment with the glass spiral in liquid air the spectrum showed no trace of the mercury lines or of the new lines in the orange and red.

This experiment was repeated in a slightly different way. The apparatus was pumped out to as low a pressure as possible (less than ·001 mm.). The spectrum was that of mercury together with the lines in the orange and red. The spiral was then placed in liquid air and the spectrum carefully watched. The mercury spectrum gradually faded away and so did the new lines, those in the red being the first to disappear. The current through the tube at the same time decreased considerably and the luminosity was feeble and showed the spectrum of the residual gas. On removing the liquid air from the glass spiral, a brilliant band spectrum of carbon monoxide appeared; this lasted for a few seconds only, and as it faded away the mercury spectrum was seen increasing in brightness and accompanied by the three lines in the orange. It took a long time for this spectrum to be brightly established again as the mercury vapour slowly came over from the spiral tube. The two red lines were never given very brightly by this tube with a platinum anode, and were only obtained at all by heating the cathode to a high temperature and having a large difference of potential between the electrodes.

In connection with the appearance of the CO spectrum it should be mentioned that the discharge tube, spiral and connecting tubes had been carefully washed out with hot chromic acid before fitting up, and that the CO spectrum was only obtained after the spiral had been placed in liquid air. No trace of the CO spectrum was seen when the experiment was repeated with the cathode hot but with no discharge passing. It was also found that the gas pressure in the apparatus was greater after removing the liquid air from the spiral tube than it was before the spiral had been cooled, although the passage of the discharge under ordinary conditions tended to decrease the gas pressure.

These experiments were repeated, using first oxygen and then hydrogen as the residual gas in the apparatus. It was found with hydrogen that the mercury spectrum and the new lines were brighter than in air or oxygen. The author has previously shown* that the discharge takes place more readily in hydrogen gas than in other gases.

* *Phil. Trans.* A, Vol. 207, p. 149, 1907.

The experiments above described indicated that the lines observed in the orange and red of the spectrum were caused by the presence of mercury vapour in the discharge tube. It was therefore expected that they would be more brilliant if a mercury anode was used. This was found to be the case. The orange lines were seen with a current as small as 2 milli-amperes, and the red lines when about 10 milli-amperes were passing through the tube.

Experiments were next made to see whether the gas condensed by immersing part of the apparatus in liquid air would give these red and orange lines when subjected to the ordinary discharge from an induction coil. For this purpose a small vacuum tube with aluminium electrodes was joined on to the discharge bulb, being separated from it by a mercury barometer cut-off so that anything condensed could be confined in a small volume by raising the level of the mercury barometer reservoir. It was hoped by this means to obtain the gas at a sufficient pressure to enable its spectrum to be studied. The apparatus was pumped down to a low pressure and then pure hydrogen was let in and pumped out, for, as already mentioned, the strange lines were best seen when the residual gas in the apparatus was hydrogen. The pressure being very low, it was with great difficulty that the discharge could be made to pass in the vacuum tube. The spectrum of the light, which was very faint, showed the hydrogen red line and the mercury yellow and green (the blue and violet regions were not examined).

The vacuum tube was then placed in liquid air and the discharge started from the lime cathode to the mercury anode in the discharge bulb. After about half an hour the vacuum tube was isolated from the discharge bulb by means of the mercury cut-off. The liquid air was then removed and the aluminium electrodes of the vacuum tube were connected to the terminals of an induction coil. By the time the spectroscope had been got into position for observing the spectrum the tube had warmed up a little, but was covered with solidified moisture from the air. The spectrum was the elementary line spectrum of hydrogen and was faint, very little luminosity being given by the tube. In a few seconds the tube became much brighter and a brilliant carbon monoxide spectrum was observed. This, after a few seconds, faded away, leaving the secondary spectrum of hydrogen. The tube meanwhile was getting much harder and the mercury lines were gradually coming into the spectrum. When the mercury spectrum had become fairly bright the three orange lines $\lambda = 6232$, $\lambda = 6121$, $\lambda = 6070$ were noticed to stand out brightly among the secondary hydrogen lines. These latter got fainter and disappeared and the tube became very hard, the mercury lines and those in the orange

being only just visible. At this stage the brightness of these lines was sometimes increased for a few seconds by reversing the induction coil, but the orange lines soon disappeared, leaving the tube quite hard and the spectrum the same as at the commencement of the experiment.

This was repeated several times and the results were always practically the same as those recorded above.

Two blank experiments were next made to see if the gases condensed in the vacuum tube were really produced by the passage of the discharge or merely formed by the heating of the lime-cathode tube. The vacuum tube was surrounded by liquid air; the lime cathode was raised to a high temperature; and the two tubes left connected for half an hour. Then, as before, the vacuum tube was isolated and connected to the induction coil. It was found to be quite hard and no gas developed as it warmed up to the temperature of the room. This experiment was repeated with exactly the same result. On repeating the experiment with the discharge passing in the lime-cathode tube the spectra of the condensed substances appeared just as in the first experiment. It thus seemed that the carbon-monoxide and the substance giving the orange lines were formed either by the passage of the discharge or distilled over owing to the extra warming of the mercury anode while the discharge was passing; this latter being the more probable explanation, seeing that some mercury must certainly have distilled over to cause the extra brightness of the mercury lines in the vacuum tube after the discharge had been passing in the adjoining tube. To test this point the vacuum tube was placed in liquid air and the mercury forming the anode in the discharge bulb was heated by means of a bunsen flame until it boiled. On then examining the discharge through the condensed substances it was found to give, for a few seconds, a faint carbon monoxide spectrum and then a bright mercury spectrum and the new orange lines. These lasted for a few minutes and then disappeared, a faint mercury spectrum remaining.

The fact that very little gas was formed in the vacuum tube by the evaporation of the substances condensed by the liquid air during these experiments, and that the gas quickly disappeared when subjected to the induction coil discharge, led me to repeat the experiments with the residual gas in the apparatus at a higher pressure, so that the discharge would pass more easily and the spectrum be better observed. Hydrogen and oxygen were tried in turn but were not very satisfactory because of the red and orange lines in the spectra of these gases. On this account helium was tried, and was found to answer very well. With this gas in the apparatus at pressures from ·005 to 3 milli-

metres I repeated both the spiral tube and the vacuum tube experiments and again found that the new orange and red lines disappeared when the mercury vapour was withdrawn, and that they were present in the spectrum of the stuff condensed while the discharge was passing in the lime-cathode tube. With helium as the residual gas in the apparatus all five lines were seen in the spectrum of the condensed substances, whereas with the other gases only the orange lines were obtained.

In some experiments made in helium gas at a low pressure, using a platinum anode in the discharge bulb, it was noticeable that the mercury spectrum, although bright to begin with, gradually faded away as the tube was worked, the orange and red lines disappearing at the same time. Since mercury would not be absorbed by the platinum anode, it seems possible that it was being used up during the passage of the discharge more quickly than the vapour could diffuse over from the mercury pump. Professor Thomson in a lecture at the Royal Institution on January 19, 1906, put forward the view that the luminosity in a lime-cathode tube is due to an increase of the internal energy of the atoms of the gas in consequence of their bombardment by the corpuscles shot out by the glowing lime. When this internal energy gets up to a certain critical value the equilibrium of the atom becomes unstable and an explosion occurs, resulting in an expulsion of corpuscles and such a shaking up of those remaining in the atom that these vibrate so vigorously that the energy radiated is sufficient to produce luminosity. If this view is correct it might mean that some of the mercury atoms would be entirely destroyed or converted into new atoms by the removal of a large number of corpuscles. This would seem to account for the disappearance of the mercury from the tube when the discharge is passed. On the other hand such an explanation of the luminosity might be taken to mean that in addition to the usual mercury lines new ones might be seen in the spectrum caused by special forms of vibration into which the corpuscles remaining in the atom are thrown. It seems probable that this is what occurs, for the new lines were never seen apart from the mercury spectrum I attempted to get them by condensing in a vacuum tube with platinum electrodes. With such a tube the mercury spectrum was always very faint, when visible at all, and no sign of the red or orange lines could be seen.

It seems therefore that these lines are probably due to mercury and the fact that they are not given by such observers as Kayser and Runge or Eder and Valenta must be due to their absence in the ordinary arc or spark spectrum or to their being extremely faint. In a recent paper Stark (*Ann. der Physik*, Vol. XXI. 1905 p. 490) gives two lines of small intensity in the vacuum tube

spectrum of mercury which are of nearly the same wave-length as two of the orange lines measured by the author. They are $\lambda = 6125$ and $\lambda = 6074{\cdot}5$, each of intensity 1. It is possible that more accurate measurements would show that my lines coincide with these.

The wave-lengths of the five lines with the oscillation frequencies deduced therefrom are:

λ	$10^8/\lambda$	
6912	14468	
		difference = 424
6715	14892	
6232	16046	
6121	16337	difference = 428
6070	16474	

From the equality of the differences between the oscillation frequencies of the first and second, and of the third and fifth of these lines, it is probable that these four lines form a pair of doublets, and are due to the same substance. If more accurate measurement should show that the lines $\lambda = 6121$ and $\lambda = 6070$ coincide with the faint lines observed by Stark in the vacuum tube spectrum of mercury, it would follow that all five are mercury lines.

On some new and obscure species of the genus Haemaphysalis of the Ixodidae.

By C. Warburton, M.A., Christ's College.

[*Received* 7 April 1908.]

The genus *Haemaphysalis* presents special difficulties to the systematist on account of the absence of characteristics which are of great specific value in other genera. There are no colour-markings, no eyes, no anal plates in the male. Moreover many of the species are feebly chitinised, and their differences therefore less pronounced. Hence it is not surprising that considerable confusion has arisen with regard to certain closely allied forms, especially the groups of which *H. flava*, Neumann, and *H. bispinosa*, Neumann, are respectively the centres, and the fact that these groups require revision does not detract in the least from the value of the admirable work done by Neumann in the classification of ticks.

To deal first with *H. flava*. Four distinct forms seem to have been confused, namely:

(1) The true *H. flava*, redescribed below,
(2) The species described below as *H. japonnica*,
(3) The species described below as *H. campanulata*,
(4) *H. neumanni*, Dönitz.

The following considerations lead to this conclusion. Examination of the specimens at the British Museum (identified by Neumann) revealed the presence of forms (1), (2) and (3) in the jar labelled *H. flava*. Examples of "*H. flava*," kindly lent by Neumann, proved to be the form (3), *H. campanulata*. Thirdly, according to Dönitz (1905), yet another form had been considered as *H. flava* by Neumann, and this Dönitz removed to a new species, *H. neumanni*.

Of these four species, then, which is the true *H. flava*?

Neumann originally (1897) described the male as having a long spur on coxa 4. Subsequently (1905) he stated that he found two closely similar forms, one with a long spur and one with a short spur, and, quite inadmissibly, he then set up the short-spurred form as the type and removed the long-spurred form to a variety, *H. flava*, var. *armata*. This evidently cannot stand, and the type must be long-spurred. If there is any variety in question it is the short-spurred form, but we believe this to be a different species altogether—the species here described as *H. japonnica*.

Unfortunately it wou d seem that in the original description

of the female he confounded the true female and that of the form now named *H. campanulata*, for he described the scutum as oval, and bright yellow or earthy yellow, whereas the true *flava* has a bright yellow scutum as broad as long, while the scutum of *H. campanulata* is darker, and longer than broad. It is clear that the true *H. flava* must be a strikingly yellow Japanese species with a long-spurred male—the species, indeed, which is re-described below.

What, then, is Neumann's short-spurred "*H. flava*"?

Dönitz thought it was the species subsequently described by him as *H. neumanni*. But this, by virtue of the dorsal spine on the 3rd article of the palp, obviously belongs to the *H. bispinosa* group, and it is probably through mere inadvertence that it was found among Neumann's *H. flavas*. The British Museum specimens make it clear that it was the species here called *H. japonnica* which Neumann had in view, for it does bear a close general resemblance to the true *H. flava*, though it differs from it otherwise than in the coxal armature. It is less easy to see how *H. campanulata* could have been confounded with *H. flava*, for it has quite a different facies, but as it was sent to us as *H. flava* and is also among the British Museum specimens, the fact is sufficiently attested. The re-arrangement here proposed seems to clear up all the difficulties.

We next come to the *H. bispinosa* group, undoubtedly the most troublesome of the whole genus. Their salient characteristic is the presence of a *dorsal* as well as a *ventral* retrograde spine on the third palpal article, and (in our view) four species are concerned, *H. hystricis*, Supino, *H. bispinosa*, Neumann, *H. parmata*, Neumann and *H. neumanni*, Dönitz*.

In 1897 Neumann described the female *H. bispinosa* from a young Indian specimen. In 1901 he described the male and modified his description of the female from specimens received from China, and in 1902, on examining the surviving remnants of Supino's types, he was led to the conclusion that his *bispinosa* was Supino's *hystricis* (from Burma), and he accordingly degraded the species *bispinosa* to a synonym of *hystricis*.

Now it seems probable that Neumann erred in supposing the Chinese specimens identical with his original Indian *bispinosa*, but that they were the true *hystricis*, which his original Indian specimen was not. On examining a large collection of Indian ticks, in 1907, I found many specimens of a species which I identified from Neumann's description as *H. bispinosa*, and which that description, as regards size, shape of the female scutum etc., fits much better than it does the specimen of *H. hystricis* which

* *H. wellingtoni*, Nuttall and Warburton, possesses somewhat similar spines, but in general character it conforms to the *H. leachi* group.

Neumann has kindly furnished for examination. Therefore it appears to me that the species *H. bispinosa*, Neumann, should be restored and the additions made to its diagnosis from the Chinese specimens cancelled. Under the circumstances I have thought it better to re-describe *H. bispinosa* from numerous males and females taken from domestic animals in India.

The two forms are so closely allied that unless seen side by side they might very easily be confounded, but when apposed the distinction is obvious, for there are various small differences besides size and chitinisation. Moreover the examination of many hundreds of Indian ticks has failed to reveal a single specimen of the large form (*H. hystricis*), whereas the small, feebly chitinised *H. bispinosa* (as I believe it to be) is fairly common. I have not, however, seen Supino's type specimens, and only know *H. hystricis* from a specimen (♀) kindly lent by Neumann, and another (also ♀) in the British Museum named by him.

Another somewhat obscure species of *Haemaphysalis* is *H. papuana*, Thorell, but the obscurity entirely arises from wrong identifications subsequent to the original description. We have received numerous specimens (from Sarawak) of a tick which is undoubtedly the true *H. papuana*, for though some points are missed in Thorell's description, his excellent figures supply the deficiencies. Canestrini (1884) confused matters by identifying some Queensland ticks as *H. papuana*, and figuring the ventral surface of the female capitulum, but his identification was probably quite wrong. The palp appears to be of a different shape, and there is no spine under the third article as there is in *H. papuana*.

In the British Museum there are two gorged female ticks labelled *H. papuana*, which are certainly not this species, but apparently something not hitherto described. A diagnosis will be found below under the name of *H. crassa*. *H. papuana* and *H. crassa* both belong to the *H. flava* group.

Haemaphysalis flava, Neumann 1897.

Syn. *H. flava*, var. *armata*, Neumann 1905.

(Redescribed from specimens taken in Japan and kindly given by Dönitz.)

Male: dull yellow, 2·1 × 1·4 mm., broadest about the level of the spiracles; punctations numerous, of medium size, regularly distributed; cervical grooves faint, converging, then separating; lateral grooves beginning about half the body length and ending immediately behind the spiracles; festoons long, curved.

Venter: yellow; spiracles white, oval, with slight blunt dorsal protuberance.

Capitulum: base rectangular, twice as broad as long, with strong sharp cornua. Palps: article 2 fairly salient but not sharply angular externally; lateral contour of articles 2 and 3 continuous; no dorsal spines; ventral border of article 2 having

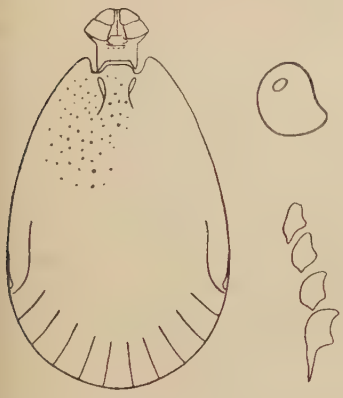


Fig. 1. *H. flava*, ♂. Dorsum, spiracle and coxae.

Fig. 2. *H. flava*, ♀. Capitulum and scutum, coxae, tarsus 4 and spiracle.

a somewhat prominent retrograde angle; a distinct retrograde spine, directed inwards at the ventro-lateral angle of article 3. Hypostome 4/4 on its distal half, then 5/5, the additional teeth being median. (Thus in the specimen described, probably variable between 4/4 and 5/5.)

Legs: a fairly strong blunt spur on coxa 1; shorter blunt spurs on coxae 2 and 3; a long sharp spur—longer than the width of the article—at the inner angle of coxa 4. Tarsi 4 rather short, about 3 times as long as broad, tapering gradually.

Female: all yellow when young, the scutum a bright yellow when the body is dark and distended; the largest specimen measured 8·5 mm.

Scutum exactly as broad as long, 1 × 1 mm. in one specimen, ·9 × ·9 mm. in another, broadest at the posterior $\frac{1}{3}$, bright yellow, with numerous fairly large punctations. Cervical grooves long, concave externally, beginning somewhat behind the anterior border as fairly deep depressions and continuing faintly to the postero-lateral margin. No lateral grooves.

Venter: spiracles white, circular, with blunt dorsal protuberance.

Capitulum: base comparatively broader than in the ♂, and with short blunt cornua; porose areas large, oval, converging anteriorly, their interval equal to their long diameter, a few

irregular punctations in the middle of the interval. Palps more salient and more sharply angular outwards, otherwise like those of the ♂. Hypostome 4/4 or 5/5.

Legs: coxa 1 with weaker spur than the ♂, a slight sharp spur at the middle of the posterior border of coxae 2 and 3, a short blunt spur at the internal angle of coxa 4. Tarsus 4 slightly longer than in the ♂, tapering gradually.

N.B. There is little doubt that Neumann based his original description of *H. flava* on specimens of more than one species. We agree with Dönitz that the species above described must be considered to be the true *H. flava*. Dönitz found reason to believe that *H. neumanni*, Dönitz, had been confounded with this species, and the British Museum specimens make it clear that *H. japonnica* and *H. campanulata* have added to the confusion. *H. japonnica* is, no doubt, the short-spurred *flava* of Neumann which he set up as the type when he removed the long-spurred form to the variety *H. flava*, var. *armata* (1905). The variety *armata* must be discarded, being, in fact, the true *flava*.

Haemaphysalis japonnica, n. sp.

Syn. *H. flava*, Neumann (in parte).

Male: 2·5 × 1·8 mm., oval, rather broad, not much narrowed in front, glossy yellow, with numerous rather shallow punctations, absent in places. Cervical grooves, oval pits; lateral grooves

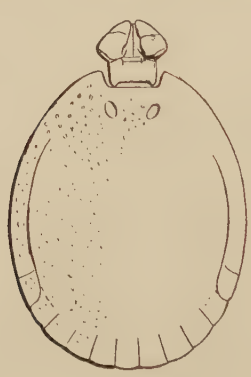


Fig. 3. *H. japonnica*, ♂. Dorsum.

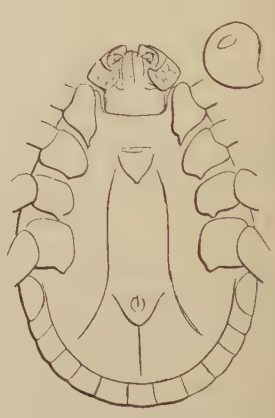


Fig. 4. *H. japonnica*, ♂. Venter and spiracle.

fairly long, markedly concave internally, including distinctly one and faintly two festoons. Festoons rather short, almost square; punctate.

Venter: somewhat lighter, glossy, punctate, genital orifice large, between coxae 2; anal groove ogival; spiracle a short comma.

Capitulum: base rather long, punctate, with short blunt cornua. Palps with article 2 only slightly salient, the lateral contours of articles 2 and 3 unbroken; no dorsal spines. Ventrally article 2 is much corrugated and forms a retrograde angle; a short spine under article 3. Hypostome spatulate, with very large corona and 5/5 small pointed teeth about equal in size.

Legs: strong; coxae large, especially coxa 4, all with a short spur, sharp on coxa 1, conical on coxae 2—4. Tarsus 4 fairly long, considerably more slender than the preceding article.

FEMALE unknown.

Description based on numerous specimens in a tube labelled *H. flava* at the British Museum. This is, no doubt, the short-spurred form of *H. flava* mentioned by Neumann (1901), but it is certainly a distinct species. In addition to the coxal armature it is distinguished from *H. flava* by its larger size and its different cervical and lateral grooves. Habitat, Japan.

Haemaphysalis campanulata, n. sp.

Syn. *Haemaphysalis flava*, Neumann (in parte) 1897.

MALE: body oval, slightly convex, about 2 × 1·4 mm., colour yellow, lighter ventrally. Scutum covering the whole dorsum; numerous very fine punctations; cervical grooves deep, sub-

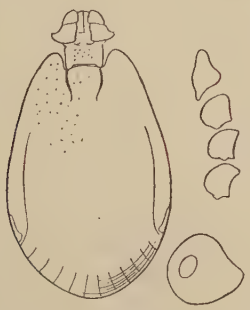


FIG. 5. *H. campanulata*, ♂. Dorsum, coxae and spiracle.

FIG. 6. *H. campanulata*, ♀. Capitulum and scutum, tarsus 4 and spiracle.

parallel, slightly convex externally. Lateral grooves beginning about the anterior third of the body and ending behind the spiracles. Festoons long and narrow, well-marked, the intervals sometimes dark.

Venter: sexual orifice broad, between coxae 2. Spiracles almost trapezoid, with very blunt rounded dorsal protuberance.

Capitulum: base rectangular, dorsally barely twice as broad as long, punctate all over, and with short blunt cornua; the rest of the capitulum notably bell-like in shape (hence *campanulata*), owing to the forwardly curved lateral projections of article 2 of the palps. Hypostome 4/4 files of rather broad teeth, about eight teeth per file, the outermost teeth the stoutest. Palps without any dorsal spines, but the ventral border of article 2 projects strongly backwards, and article 3 has a well-marked ventral retrograde spine.

Legs: coxae each with a short blunt spur. Tarsi 4 very short and thick, ending in a somewhat abrupt slope, the false articulation about the middle of the article.

Female (young): yellow, somewhat parallel-sided, sometimes attaining 7×4 mm. when distended. *Scutum* distinctly longer than broad, glossy brown or yellow, cordiform, finely punctate; cervical grooves well-marked, rather far apart, at first convex outwardly, then turning outward. No lateral grooves. Dorsum with marginal grooves including two festoons. Venter yellow, spiracles like those of the ♂ but with dorsal protuberance even less marked.

Capitulum: base broader and shorter than in the ♂, with less distinct cornua; porose areas oval, their axes converging forward, far apart, the interval twice their diameter, a narrow longitudinal pit midway between them. The rest of the capitulum like that of the ♂ but even more markedly bell-shaped. Hypostome 4/4, with teeth rather narrower than in the ♂. *Legs*: coxae as in the male, tarsus 4 short, thick, somewhat humped.

Description based on numerous specimens taken from Chinese dogs in Mongolia by Major M. L. Hearn, and received by us from Colonel Skinner in 1906. They agreed in every respect with specimens kindly lent by Neumann as *H. flava*, and with others so named by him at the British Museum.

Haemaphysalis papuana, Thorell 1882.

Male: $2{\cdot}1 \times 1{\cdot}7$ mm., yellow, flat, broadest towards the posterior end, coarsely pitted over the whole scutum except along certain inconstant ridge-like tracts where the punctations are absent; festoons about as broad as long, the intervals often dark and broadening distally; cervical grooves oval pits with slight shallow continuation; lateral grooves very short and ill defined, beginning at about half the body length and ending behind the spiracles.

Venter: yellow-brown, darker than scutum, glabrous; finely punctate; sexual orifice broad, between coxae 2; sexual grooves far apart, nearly parallel; festoons well-marked ventrally, with dark intervals. Spiracles yellow, oval with fairly pronounced dorsal protuberance.

Capitulum: base rectangular, with slightly convex sides, and broad blunt cornua, coarsely punctate dorsally. Palps only slightly salient, the external angle of article 2 fairly sharp, its inner border has, dorsally, an inward projection at its distal end. No distinct dorsal spines but the posterior border of article 3 sharply angular

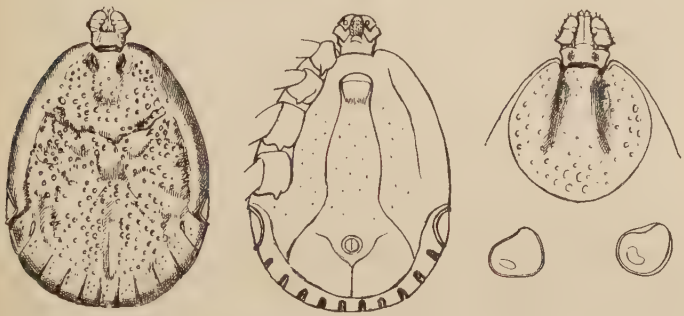


Fig. 7. *H. papuana*, ♂ dorsum and venter, ♀ capitulum and scutum, ♂ and ♀ spiracles.

in the middle. Article 2 is sharply angular ventrally, and there is a short retrograde ventral spine on article 3. Hypostome 4/4.

Legs: a short sharp spur on coxa 1, a very slight spur near the middle of the posterior border of coxae 2 and 3, a very short spur at the inner angle of coxa 4. Tarsi relatively short and somewhat humped.

Female. *Scutum* nearly circular, bright yellow, coarsely pitted. Cervical grooves shallow, concave externally.

Capitulum: base broader and shorter than in the ♂, with very slight cornua, sides somewhat convex. Porose areas large, oval, far apart, converging anteriorly. Palps longer and narrower than in the ♂; article 2 with sharper external angle, its inner dorsal contour like that of the ♂. Spiracle round, with blunt dorsal protuberance, yellow or white.

Legs: coxae as in the ♂. Tarsi 4 tapering gradually, the distal pseudo-articulation rather long.

The Nymphs differ very little from the females except in the absence of vulva and of porose areas, and the small size of the spiracle. They have the same yellow scutum and their palps present similar characteristics.

N.B. Thorell's excellent figures leave no doubt as to the identity of this species, and shew clearly various characteristics not mentioned in his description, such as the "ridge-like tracts," the short indefinite lateral grooves, and the inward dorsal projection of article 2 of the palps mentioned above. If Canestrini

correctly identified his specimens his figure of the female capitulum is incorrect, especially in the absence of the very distinct ventral spine on the third article of the palp. The figure is evidently drawn from a balsam specimen, in which case the spine would probably be difficult to see, but the identity is doubtful.

Thorell's specimens (1 ♂ and 1 ♀) were from New Guinea; those of Canestrini from Queensland. The size given by Thorell for the male (ca. 3 × 2 mm.) is apparently only roughly approximate, and doubtless includes the capitulum.

We have received several specimens (♂, ♀ and nymphs) from Dr Wellington, Sarawak, Borneo.

Haemaphysalis crassa, n. sp.

Male unknown.

Female (replete) 11 × 7 mm., red-brown. *Scutum* longer than broad, 1·3 × 1 mm., dark brown, roughly hexagonal, with broadly

Fig. 8. *H. crassa*, ♀. Capitulum and scutum, tarsus 4 and spiracle.

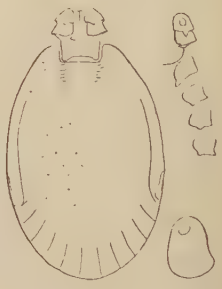


Fig. 9. *H. bispinosa*, ♂. Dorsum, coxae and spiracle.

rounded base and very anterior lateral angles, the postero-lateral borders only slightly converging, and twice as long as the antero-lateral borders; very rugged, with numerous deep punctations, many of them confluent. Cervical grooves well-marked extending for two-thirds of the length, enclosing a wide area.

Spiracle a very short comma (or nearly round with distinct dorsal protuberance).

Capitulum massive; base rectangular, without cornua, porose areas very large and circular, their diameter greater than their interval; some deep punctations between them. Palps massive corrugated dorsally, article 2 bluntly salient, the lateral contour o

articles 2 and 3 unbroken; no dorsal spines; a small sharp spine under article 3. Hypostome 5/5, with hardly any corona.

Legs: a short sharp conical spur on all the coxae, longest on coxa 4. Tarsus 4 rather short, tapering to a sharp point, pad long.

Description based on two gorged ♀ at the British Museum, in a tube labelled *Haemaphysalis papuana.*

Haemaphysalis bispinosa, Neumann 1897, *non* 1901 and 1902.
Syn. *H. bispinosa,* Warburton 1907.

Male: 2 × 1·3 mm., yellow or brown (in well-chitinised specimens), long oval, broadest in the middle, glabrous, uniformly punctate with medium inconspicuous punctations; cervical grooves very faint, lateral grooves long, well-marked, ending behind spiracles; festoons very long.

Venter: spiracles white, oval, broadest posteriorly, almost without dorsal protuberance.

Capitulum: base fairly long, broadly rectangular, with straight sides and moderate cornua; palps only slightly salient, articles 2 and 3 about equal in size and equally angular externally; no spines on article 2, a short, sharp retrograde spine at the middle of the dorsal border and at the middle of the ventral border of article 3. Hypostome 4/4 with equal teeth.

Legs: a moderate, sharp spur on coxa 1; a very slight protuberance on coxae 2—4.

Female: scutum yellow or brown, nearly circular, 1 × ·9 mm. with unbroken contour; cervical grooves beginning rather behind the anterior margin as fairly deep furrows which converge and then curve outward, almost reaching the postero-lateral border; numerous regularly distributed punctations of medium size; no lateral grooves.

Venter: spiracles white, nearly circular, practically without dorsal protuberance.

Capitulum: base broader than in the ♂, the sides straight, the cornua short and blunt; porose areas fairly large, far apart, oval, diverging anteriorly, not very clearly defined. Palps as in the ♂; hypostome 4/4, with teeth of equal size.

Legs: coxae as in the ♂; tarsus 4 long (at least 4 times as long as broad), tapering very gradually.

Description based on numerous specimens from India and Ceylon, where it appears to be common.

N.B. It appears to us that Neumann has wrongly degraded this species *H. bispinosa* to a synonym of *H. hystricis.* Our acquaintance with the latter species rests solely on a female kindly sent us by Neumann and another female which we have examined in the British Museum. If this, as we believe, be the true *hystricis*

it cannot possibly be the species intended by Neumann's original description of *bispinosa*, but a much larger and more chitinised form. Neumann gives the size of his young ♀ *bispinosa* as $2 \times 0{\cdot}5$ mm. The breadth given is no doubt an error, and should probably be 1·5 mm., but even so it is far too small for *hystricis*. Our unfed ♀ measured 3 mm. and its scutum alone $1{\cdot}2 \times 1{\cdot}5$ mm. Again he describes the scutum as "lozenge-shaped." This could not by any means apply to *hystricis*, which has a scutum elliptical and broader than long. Moreover his specimen was from India, and his description and figures agree well with a species which we have found to be fairly common in India and Ceylon, and which is here fully described.

Haemaphysalis hystricis, Supino 1897.

Syn. *H. bispinosa*, Neumann 1901 (*non* Neumann 1897).

Female (unfed). *L.* = 3 mm., broad oval, yellow. *Scutum* elliptical, broader than long ($1{\cdot}2 \times 1{\cdot}5$ mm.). Broad, shallow,

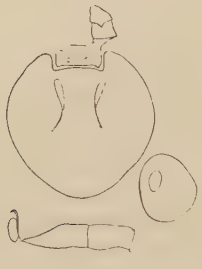


Fig. 10. *H. bispinosa*, ♀. Capitulum and scutum, tarsus 4 and spiracle.

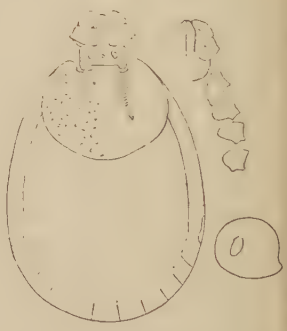


Fig. 11. *H. hystricis*, ♀. Dorsum, coxae and spiracle.

nearly parallel cervical grooves; no lateral grooves, punctate all over. Dorsum with well-marked marginal grooves, including two festoons.

Venter: spiracle whitish, circular, with well-marked dorsal process.

Capitulum (·7 mm. long): base rectangular (·6 mm. broad), with blunt cornua; porose areas very small and far apart, oval, converging in front. Palps only slightly salient, the lateral contour of articles 2 and 3 only slightly interrupted, a fairly strong dorsal retrograde spine on article 3, and a stronger ventral retrograde spine on the same article. Hypostome almost entirely covered by

sharp teeth, 4/4, the outer the stronger, the inmost very small; corona small.

Described from a specimen kindly lent by Neumann. Though closely allied to *H. bispinosa* it is a much larger and more highly chitinised species, with much stronger legs and very much larger spiracle. The following differences may also be noticed:

H. hystricis ♀	*H. bispinosa* ♀
scutum broader than long (1·2 × 1·5 mm.)	slightly longer than broad (1 × ·9 mm.)
cervical grooves broad, shallow, nearly parallel	well-marked, deep and converging, then shallow and diverging
porose areas very small, oval	medium, round
spiracle circular, with distinct process	oval, without process
hypostome 4/4, well covered with small teeth, larger at the sides	4/4, less covered, teeth equal

H. parmata, Neumann, and *H. neumanni*, Dönitz, have been adequately described, and a few notes with regard to them will be sufficient here. They are very closely allied to the foregoing species, and it is difficult in any description to make their differences clear, though they are undoubtedly distinct.

H. parmata is a very small, feebly chitinised African tick (from domestic animals in the Cameroons), and the male furnished us by Neumann measures no more than 1·8 × 1·1 mm. It is dull yellow, not much narrowed in front, and with very short lateral grooves. The basis capituli is very short and broad, and the cornua diverge somewhat. The female scutum is nearly circular, but rather broader than long (·7 × ·9 mm. in our specimen), and light glossy yellow, and the spiracle is circular. The dentition in both sexes is 4/4.

H. neumanni varies somewhat in size, but the male averages about 2·3 × 1·4 mm., and is oval, with long lateral grooves. The female scutum is like that of *H. bispinosa* with the lateral angles rather more pronounced, and the spiracle has a blunt dorsal process. Its dentition is 5/5 or sometimes 6/6 (as in our specimen, given by Dönitz). It infests domestic animals in Japan.

On Monotone Sequences of Continuous Functions. By W. H. Young, Sc.D., F.R.S.

[*Received* 2 February, 1908.]

§ 1. In the following note I obtain the necessary and sufficient condition that a function should be representable as the limit of a monotone sequence of continuous functions, the word "continuous" being used in the generalised sense, when $+\infty$ is distinguished from $-\infty$. The result obtained is that for a diminishing sequence the function must be upper semi-continuous, while for an increasing sequence the function must be lower semi-continuous.

In § 2 I shew that this condition is necessary. The method and notation here adopted are those of my paper on "Uniform and Non-uniform Convergence and Divergence of a Series of Continuous Functions and the Distinction of Right and Left," *Proc. L. M. S.*, Series 2, Vol. VI., pp. 29—51. I also use the conception of "uniform divergence at a point" given on p. 36, line 13, where, it should be noted, the sequence of functions considered is a sequence of continuous functions. The definition of uniform divergence there given is only a suitable one in this case.

In § 3 I give a generalisation of the result of § 2.

In §§ 4 and 6 I shew that the results of §§ 3 and 5 hold for any number of independent variables.

In § 5 I shew that this condition is sufficient.

In § 7 I give a new definition of a Riemann integral of a discontinuous function, bounded or unbounded, based on the theorems of §§ 2 and 3.

§ 2. Theorem. *If* $f_1(x), f_2(x), \ldots$ *is a series of continuous functions (bounded or not), having a definite limit* $f(x)$, *finite or infinite, at each point* x, *and such that*

$$f_1(x) \geqslant f_2(x) \geqslant f_3(x) \geqslant \ldots,$$

then (1) *the function* f *is upper semi-continuous, and*

(2) *there are no invisible points* of non-uniform convergence or divergence, in fact*

(3) $$\chi_L(x) = \psi_L(x) \leqslant \pi_L(x),$$
$$\pi_L(x) = f(x).$$

A similar pair of relations holds, of course, on the right.

* So that the function f is discontinuous wherever the series is non-uniformly convergent or divergent.

For let P be any point, and Q a point on the left of P. Then, since $f_n(x)$ is a continuous function, there is a point x_n of the closed interval (P, Q) at which $f_n(x)$ *assumes* its least value in the interval (P, Q), say

$$\begin{aligned} f_n(x_n) &= L_{n,Q} \\ &\geqslant f_{n+1}(x_n) \geqslant f_{n+2}(x_n) \geqslant \dots \\ &\geqslant f(x_n) \\ &\geqslant \text{lower bound of } f(x) \text{ in the interval } (P, Q). \end{aligned}$$

Allowing n to increase without limit, we see that the lowest possible limit L_Q of $L_{n,Q}$ is also $\geqslant$ the lower bound of $f(x)$ in (P, Q).

Now moving the point Q up to P as limit, L_Q has, by the definition of the left-hand chasm function, the limit $\chi_L(P)$, while the lower bound of $f(x)$ in (P, Q) has, by the definition of the left-hand associated lower limiting function, the limit $\psi_L(P)$, thus

$$\chi_L(P) \geqslant \psi_L(P).$$

Now it being known that in all cases,

$$\chi_L(P) \leqslant \psi_L(P) \leqslant \phi_L(P) \leqslant \pi_L(P),$$

we get the first of the relations (3), viz.

$$\chi_L(P) = \psi_L(P) \leqslant \phi_L(P) \leqslant \pi_L(P),$$

ϕ_L being the associated upper limiting function and π_L the peak function on the left.

To obtain the second of the relations (3), we have in like manner a point x_n' of the interval (P, Q) at which $f_n(x)$ *assumes* its greatest value in (P, Q), say

$$\begin{aligned} f_n(x_n') &= M_{n,Q} \\ &\leqslant f_{n-1}(x_n') \leqslant M_{n-1,Q}. \end{aligned}$$

Hence $$M_{n,Q} \geqslant M_{n+1,Q} \geqslant M_{n+2,Q} \geqslant \dots \geqslant M_Q \geqslant \pi_L(P),$$

and therefore, $$f_n(x_n') \geqslant \pi_L(P).$$

Now let n be fixed and Q move up to P as limit, then the point x_n', if not already the point P itself, moves up to P as limit, so that, $f_n(x)$ being continuous,

$$f_n(P) \geqslant \pi_L(P).$$

Now let n increase without limit, and we get

$$f(P) \geqslant \pi_L(P),$$

whence, it being known that in all cases,

$$f(P) \leqslant \pi_L(P),$$

we get the remaining relation in (3), viz.

$$f(P) = \pi_L(P).$$

From this it follows also that

$$f(P) \geqslant \phi_L(P),$$

which shews that f is an upper semi-continuous function on the left.

The relation (3) shews that if the upper and lower associated functions ϕ_L and ψ_L coincide with f, the peak and chasm functions π_L and χ_L are equal, in other words, at a point of continuity on the left there is uniform convergence on the left, or which is the same thing, there are no invisible points of non-uniform convergence on the left.

Similar relations holding of course on the right, this proves the whole theorem.

§ 3. Bearing in mind that the investigations of my L. M. S. paper, referred to above, apply at a point at which the generating functions $f_1, f_2, \ldots$ are all continuous, and further that any countably infinite set of pointwise discontinuous functions defined for any interval have in common an everywhere dense set of common continuities, the proposition in the text may be generalised as follows:

THEOREM*. *Let $f_1, f_2, \ldots$ be a decreasing monotone sequence of upper semi-continuous functions having f for limiting function, then f has in every interval a point of upper semi-continuity.*

In fact the second part of the preceding argument applies, as it stands, at a common point of continuity of $f_1, f_2, \ldots$, if we bear in mind that the upper semi-continuous function $f_n(x)$ necessarily assumes its upper bound in (P, Q), by the well-known property of upper semi-continuous functions.

§ 4. So far we have assumed that the functions concerned are functions of a single variable. We have, in fact, treated the left and right separately. There is, however, nothing to prevent our dropping the suffixes L and R, and defining the various functions introduced in the argument in such a way that the proof applies to functions of m variables. The intervals terminating at the point P will be replaced by regions surrounding the point P.

The various theorems of my L. M. S. paper, above referred to, hold, in fact, for functions of any number of variables, exception

* This theorem gives only part of the truth. The function f is indeed upper semi-continuous throughout the interval or region. Moreover if $f_1, f_2, \ldots$ are *upper semi-continuous at a point P only* and from a decreasing sequence in its neighbourhood, then f is upper semi-continuous at P. See my paper "On Functions Defined by Monotone Sequences, and their Upper and Lower Bounds," *Mess. Math.* New Series, No. 442 (1908), p. 151.

being made of those which deal with the distinction of right and left.

It follows that *a monotone decreasing (increasing) sequence of continuous functions of m variables has as limiting function an upper (lower) semi-continuous function, whether the various functions concerned are bounded or not, and that there are no invisible points of non-uniform convergence or divergence.*

§ 5. THEOREM. *Conversely, if $f(x)$ is an upper (lower) semi-continuous function, bounded or unbounded, it is representable as the limit of a decreasing (increasing) monotone sequence of functions which are continuous, but not necessarily finite, each of which may be so chosen as to have a finite lower (upper) bound.*

Case 1. First let $f(x)$ be upper semi-continuous, bounded, and never negative*.

Divide the fundamental segment (a, b) in successive stages into 2, 4, 8, ... equal divisions. The points of division used at one stage remain points of division at all subsequent stages, and ultimately become dense everywhere; they are called *the primary points*, and are countable. The remaining points, other than the extreme points a and b, are called *secondary points.*

If x be a primary point used in the nth division, it is the end-point of two abutting parts, forming together a closed segment to which x is internal. We take the value of f_n at x to be the upper bound of f in this segment. At a and b we take as value of f_n the upper bound of f in the single part having the point in question as end-point.

We have thus a finite positive value of $f_n(x)$ at a finite number of points. Erecting ordinates at these points of height $= f_n$ there, we join the tops of adjacent ordinates by straight lines. The continuous line so obtained is taken to define

$$y = f_n(x)$$

at every point of the segment (a, b).

Since the upper bound of f in a closed segment is not less than the upper bound of f in a closed segment contained in the first, we see that at each primary point, and at the extremes a and b,

$$f_{n-1} \geqslant f_n.$$

The same is then true at the secondary points, since the straight line joining two points on two ordinates lies above that

* The case where $f(x)$ is bounded has been proved by Baire, cp. Hobson's *Functions of a Real Variable*, where the proof given is substantially that used in case (1) above. The fact that the sequence obtained is monotone does not seem to have been mentioned, and had no particular interest in connection with Baire's researches. The form of the proof given above avoids the use of an ϵ, and is required for subsequent generalisation.

joining two lower points on the same ordinate, and the same is true if one of the second pair of points coincides with one of the first. Thus *the sequence of continuous functions obtained is monotone.*

We have only to shew that the sequence has $f(x)$ as limit.

Now by the definition of Baire's upper limiting function ϕ_B, the construction gives at any primary point

$$\operatorname*{Lt}_{n=\infty} f_n(x) = \phi_B(x),$$

and, since f is upper semi-continuous,

$$f(x) = \phi_B(x),$$

which proves that at each primary point,

$$\operatorname*{Lt}_{n=\infty} f_n(x) = f(x).$$

The same holds at the extremes, where, of course, we are concerned with one side only of the point.

On the other hand at a secondary point x, x_n' and x_n'' being the nearest points of division at the nth stage, on the left and right of x respectively, it follows from the construction that $f_n(x)$ lies between $f_n(x_n')$ and $f_n(x_n'')$.

Now $f_n(x_n')$ was defined as the upper bound of $f(x)$ in an interval which clearly contains x as internal point, and, as n increases indefinitely, these intervals lie one inside the other and have x as sole common internal point. Thus, by the definition of Baire's upper limiting function,

$$\operatorname*{Lt}_{n=\infty} f_n(x_n') = \phi_B(x).$$

Since the same is true of $\operatorname*{Lt}_{n=\infty} f_n(x_n'')$, it follows that the same is true of $\operatorname*{Lt}_{n=\infty} f_n(x)$, which is intermediate between the two limits. Since f is upper semi-continuous, it follows, therefore, that

$$\operatorname*{Lt}_{n=\infty} f_n(x) = f(x).$$

This last equation has therefore been shewn to hold at every point, which proves that $f(x)$ *is the limit of the monotone sequence of continuous functions* $f_n(x)$ *constructed.*

This construction was such that $f_n(x)$ was never negative, since $f(x)$ was never negative, and the sequence was, of course, monotone decreasing. If now we replace $f_n(x)$ by

$$f_n(x) + \frac{1}{2^n},$$

the new sequence will still be monotone decreasing and have the same limit as before, the generating function is however always

positive. This proves that an upper semi-continuous function which is bounded and never negative, can be expressed as the limit of a monotone decreasing sequence of continuous bounded positive functions.

Case 2. Let $f(x)$ be lower semi-continuous, bounded, and never negative.

We have in the preceding discussion only to use the lower limit instead of the upper limit, and so express $f(x)$ as the limit of a monotone increasing sequence of continuous bounded functions which are never negative. It is to be remarked that we cannot now ensure the generating function being always +, since the addition of a decreasing sequence of small quantities such as was used before might destroy the monotony of the sequence.

Case 3. Next let $f(x)$ be *any* upper semi-continuous function. At every point where f is positive put

$$u(x) = f(x) + A, \quad v(x) = -A,$$

and elsewhere

$$u(x) = A, \qquad v(x) = f(x) - A.$$

Thus at every point

$$u(x) + v(x) = f(x).$$

It is obvious that u and v are both upper semi-continuous functions, one of which is positive and $\geqslant A$ and the other negative and $\leqslant -A$ everywhere.

Now u is always $\geqslant A$, and $v \leqslant -A$. Thus

$\frac{1}{u}$ is lower semi-continuous and lies between 0 and $\frac{1}{A}$,

$\frac{1}{v}$ is lower semi-continuous and lies between 0 and $-\frac{1}{A}$,

which makes

$-\frac{1}{v}$ upper semi-continuous, and lying between 0 and $\frac{1}{A}$.

Thus, by case (2),

$$\frac{1}{u} = \operatorname*{Lt}_{n=\infty} u_n',$$

where u_n' is a continuous bounded function which is never negative, and the sequence is monotone increasing; whence,

$$u = \operatorname*{Lt}_{n=\infty} \frac{1}{u_n'} = \operatorname*{Lt}_{n=\infty} u_n, \text{ say,}$$

where u_n *is a continuous (but in general unbounded) positive function, and the sequence is monotone decreasing.*

Similarly, by case (1)

$$-\frac{1}{v} = \underset{n=\infty}{\text{Lt}}\ v_n',$$

where v_n' is a bounded positive continuous function, and the sequence is monotone decreasing. Thus

$$-v = \underset{n=\infty}{\text{Lt}}\ \frac{1}{v_n'} = \underset{n=\infty}{\text{Lt}}\ v_n'',$$

where v_n'' is a bounded positive continuous function, and the sequence is monotone increasing. Thus finally

$$v = \underset{n=\infty}{\text{Lt}}\ -v_n'' = \underset{n=\infty}{\text{Lt}}\ v_n,$$

where v_n *is a bounded negative continuous function and the sequence is monotone decreasing.*

Since u_n is continuous and never negative and v_n bounded and continuous, their sum

$$u_n + v_n = f_n, \text{ say},$$

is continuous and has a finite lower bound, so that, though it may be $+\infty$, it is nowhere $-\infty$.

Also, since

$$u_n(x) \geqslant u_{n+1}(x),$$

and

$$v_n(x) \geqslant v_{n+1}(x),$$

it follows that

$$f_n(x) = u_n(x) + v_n(x) \geqslant u_{n+1}(x) + v_{n+1}(x) \geqslant f_{n+1}(x),$$

so that the sequence $f_n(x)$ is monotone decreasing. Also

$$\begin{aligned} \underset{n=\infty}{\text{Lt}}\ f_n(x) &= \underset{n=\infty}{\text{Lt}}\ [u_n(x) + v_n(x)] \\ &= \underset{n=\infty}{\text{Lt}}\ u_n(x) + \underset{n=\infty}{\text{Lt}}\ v_n(x) \end{aligned}$$

(since these limits are nowhere both infinite), which

$$= u(x) + v(x) = f(x).$$

Thus we have expressed $f(x)$ as the limit of a monotone decreasing sequence of continuous functions $f_n(x)$, each of which has a finite lower bound.

Case 4. When $f(x)$ is *any* lower semi-continuous function, $-f(x)$ is an upper semi-continuous function, and can be expressed as above, whence the required expression for $f(x)$ follows immediately.

This proves the whole theorem.

Cor. *Any upper (lower) semi-continuous function whose upper (lower) bound is finite, may be expressed as the limit of a monotone descending (ascending) sequence of bounded continuous functions.*

§ 6. The same is true, if, instead of one variable x, we understand by x the ensemble of two or more variables, i.e. if the point x, instead of being a point on a straight line, is a point in the plane, or in n-dimensional space.

Suppose, for definiteness, that x is a point in a plane, and that the upper semi-continuous function $f(x)$, which in case (1) is never negative, is defined for a finite closed region R. Enclose the region in an equilateral triangle, and assign to f at all points of this triangle outside R the value zero, which does not disturb its upper semi-continuity.

This equilateral triangle we divide successively into 4, 4^2, ... equal equilateral triangular parts, just as, on the straight line, we used equal segments. The primary points are now the vertices of the triangles, the extremes, those vertices which lie on the periphery of the large equilateral triangle, or fundamental triangle. At each primary point used at the nth division, and at each extreme point used at the nth division, we define f_n, as before, as the upper bound of f in all the triangles meeting at that primary or extreme point. Erecting ordinates of height f_n at the vertices of any triangular part, we lay through their three tops a plane, which serves, as before the straight line, to define f_n at every point of that triangular part. The proof that the series of continuous functions f_n so defined is monotone and has f as limit is of precisely the same nature as before.

In case (2) the value to be assigned to f outside the closed region R, is, not zero, but the upper bound of f, in order that f may remain lower semi-continuous.

Having in this way obtained the representation of a bounded semi-continuous function which is not negative for every point x of a triangle containing the closed region R, the same representation does for the region R itself, x being now a point of that closed region alone. This representation can then be applied in case (3), as on the straight line. The reasoning in case (4) is the same in all dimensions.

The above indicates how the proof must be verbally modified when x is a point in a plane. In the case of S_3 we use, instead of a triangle, a regular tetrahedron, and in S_n a regular $(n+1)$-gon.

§ 7. The results of the previous articles enable us to give a definition of an absolutely existent integral (Riemann integral) which applies equally whether the integrand is bounded or unbounded, whether the range of integration be a segment, or an area, or indeed any closed n-dimensional region, whatever be the nature of its boundary. This definition is as follows:

Form the associated upper limiting function ϕ of the given function f. Express it as the limit of a monotone descending

sequence of continuous and, in general, unbounded functions $\phi_1, \phi_2, \ldots$. If ϕ_n be unbounded, express it as the limit of a monotone ascending uniformly convergent, or divergent, sequence of bounded continuous functions $\phi_{n,1}, \phi_{n,2}, \ldots$. Then the upper integral of f, $\overline{\int} f(x)\,dx$, is defined by the following equations,

$$\overline{\int} f(x)\,dx = \operatorname*{Lt}_{n=\infty} \int \phi_n(x)\,dx,$$

$$\int \phi_n(x)\,dx = \operatorname*{Lt}_{r=\infty} \int \phi_{n,r}(x)\,dx^*.$$

The lower integral of f, $\underline{\int} f(x)\,dx$, being similarly defined, we have a Riemann integral when, and only when, the upper and lower integrals have the same value for the interval, or region, of integration considered.

It will be observed that the integration is reduced to that of a bounded continuous function†, which may be supposed defined in any of the various ways which is convenient, e.g. in the case of a single independent variable, as the inverse differential coefficient of the integrand.

Assuming, further, that such a definition has been given for the integration of a bounded continuous function with respect to a closed set of points, the above gives us a definition of the integral of any function with respect to such a set.

The definition arises naturally from the application of the principle of the conservation of mathematical laws. In my "General Theory of Integration‡," indeed, I proved the fundamental proposition that, in the case of bounded functions, the upper integral of a function is equal to that of its associated upper limiting function. This proposition, applied now to unbounded functions, appears in the above as itself a definition of an improper integral.

On the other hand, as unbounded and discontinuous functions present themselves most naturally as the limits of bounded continuous functions, it is a natural extension of the meaning of the

* It is necessary of course to shew that these limits which from the very nature of the sequences exist, are independent of the particular mode in which the constituent functions of the sequences are chosen so long as they are monotone. This presents no great difficulty.

† Which may be taken to be a polynomial. In fact by an extension of a theorem of Weierstrass any unbounded continuous function may be expressed as the uniform limit of a polynomial. I have given a proof of this theorem in a paper recently presented to the London Mathematical Society. Thus the problem of integration is reduced to that of integrating a positive integral power of x.

‡ *Phil. Trans.* Vol. 204 (1905).

word integration to define the integrals of the former as limits of integrals of the latter.

It should be remarked that our definition shares with that of De La Vallée Poussin the disadvantage of applying only to absolutely existent integrals. The fact, however, that it employs only well-defined series of continuous functions, and that its form is independent of the number of dimensions, and of the character of the region of integration*, gives it certain advantages over that of Harnack. These advantages are best brought out in a systematic development of the theory of Riemann integration based on the new definition. Such an exposition of the theory I hope to be able to publish shortly.

* It should be remarked that, when the region of integration is infinite, an upper and lower integral, as defined in this paper, will not exist unless the continuous function $\phi_{n,r}$ possesses an integral over that region. This case requires further discussion. We might so modify our definition that the region of integration is the whole plane, or S_n, by ascribing, in fact, the value zero to the original function at every point at which it is not already defined. But this would not completely remove the difficulty, a continuous function has not necessarily an integral, finite or infinite, over, for example, the whole infinite plane, according to the usual definition. Even when the region is finite, if it be bounded by a curve of positive area, the definition requires care.

Moreover even when all this can be adjusted, the extension of the definition of § 7 to an infinite region of integration may still be unallowable owing to the violation of the fundamental law that the integral over an infinite region S is to be the limit of the integral over a finite region S'. It is, in fact, not *a priori* allowable to change the order of the limits and write

$$\operatorname*{Lt}_{r=\infty}\operatorname*{Lt}_{S'=S}\int_{S'}\phi_{n,r}(x)\,dx=\operatorname*{Lt}_{S'=S}\operatorname*{Lt}_{r=\infty}\int_{S'}\phi_{n,r}(x)\,dx.$$

Unless this is true we cannot assert that, defining the integrals as in § 7,

$$\operatorname*{Lt}_{S'=S}\int_{S'}\phi_n(x)\,dx=\int_S\phi_n(x)\,dx.$$

On the Fauna of the Bradford Coke Bed Effluent,

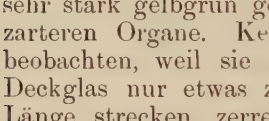
von Dr A. Meixner.

(Communicated by Mr A. E. Shipley.)

[*Read* 4 May 1908.]

Im Bodensatz der eingesandten Probe fanden sich: *Trinema* sp., ein Rhizopode aus der Familie der *Gromiidae* (sowohl lebende Exemplare als insbesonders leere Gehäuse), ein *Rotatorium*: die spannerartig kriechende, augenlose *Callidina* Ehrbg., eine *Nematoden*-Art aus der Familie der *Anguillulidae* in sehr bedeutender Individuenzahl, ein *Annelide*: *Aeolosoma ehrenbergii* Oerst. und aus dem Tribus der rhabdocoelen Turbellarien zahlreiche *Stenostoma* einer Species, die im Habitus und Betragen ganz mit *St. unicolor O. Schm.* übereinstimmt; doch sind Einzelthiere nur cca. 0·25 mm. lang und 0·06 mm. breit; Ketten von 2 Zooiden sind 0·4 mm. lang, während Vejdovský für "die kleinste Kette mit 2 Zooiden...kaum 2 mm. Länge" angiebt. Die Anatomie—soweit am lebenden Thier erkennbar—stimmt gut mit Vejdovský's* Beschreibung von *St. unicolor*. Die "Vagusganglien" konnte ich nicht erkennen. Die "lymphatischen Körperchen" waren zumeist sehr stark gelbgrün gefärbt und verhinderten das Erkennen der zarteren Organe. Ketten lassen sich schon deswegen schwer beobachten, weil sie sich, sobald ihnen der Raum unter dem Deckglas nur etwas zu enge wird, sogleich gewaltsam in die Länge strecken, zerreissen und alsbald zerfliessen. Bei Einzelthieren gelingt es ungleich leichter, sie in ihren Bewegungen einzuschränken und zu beobachten. Von über 30 untersuchten Exemplaren lieferten mir nur 2 deutliche Bilder.

Die "Chitinbläschen" od. "schüsselförmigen Organe" scheinen nicht unmittelbar mit dem Epithel verbunden zu sein, sondern tiefer im Mesenchym zu liegen. Sie zeigen sich bei keiner Lage völlig kreisrund, sondern höchstens oval (1), meist aber zeigen sie einen bohnenförmigen Umriss (2, 3). Demnach sind sie entweder oval-schüsselförmig—obgleich ich die dann bei höherer od. tieferer Einstellung zu erwartende, in Fig. 4 punktiert gezeichnete Contour nie erkennen konnte—oder einfach gebogen. Es sind homogen erscheinende, nicht aus kleineren Kügelchen zusammengesetzte Gebilde.



1 2 3

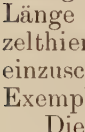


Fig. 4.

Der Hauptexcretionscanal biegt nach Vejdovský bald erst im Kopflappen (*l.c.* Tab. v, Fig. 1), bald schon

* F. Vejdovsky, *Thierische Organismen der Brunnenwässer von Prag.* Prag. 1882, pag. 54, tab. v. fig. 1--12.

hinter dem Pharynx (*l.c.* Tab. v, Fig. 2) in einen rücklaufenden Ast um. Diese scheinbare Variabilität glaube ich, nach Beobachtungen an *einem* sehr durchsichtigen Exemplare (Fig. 5) dadurch erklären zu können, dass der Ursprung des rücklaufenden Astes (*ehr*) zwar hinter dem Mund (*mo*) und dem Pharynx liegt, von hier aber ein medianer Excretionsstamm (*a*) sich in den Kopflappen hinein fortsetzt und sich daselbst verästelt. Weniger deutlich waren von obiger Stelle entspringende Seitenäste (*l*) zu erkennen, die unweit der Körperseiten umbogen und nach hinten liefen.—In den hinteren Körperpartieen konnte ich nur einen Excretionsstamm (*eh*) in der Medianlinie feststellen und glaube nicht, dass, wie Vejdovský dies darstellt (*l.c.* Tab. v, Fig. 1), der rücklaufende Ast in die Excretionsblase (eine minimale Erweiterung) einmündet. Er verästelt sich wahrscheinlich längs des Darmes.

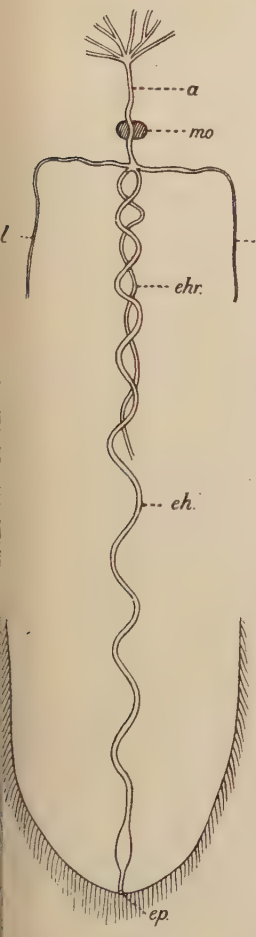


Fig. 5.

Den von langen Cilien umstellten Excretionsporus (*ep*) habe ich an einem Thiere in Thätigkeit gesehen; er liegt hiebei völlig terminal. Bei der Kriechbewegung verschiebt er sich zeitweise etwas auf die Ventralseite.

Die Fortbewegung der Thiere erfolgt, wenn sie genügend Raum haben, durch Rudern mit den Cilien, sowohl vorwärts als rückwärts; durch den Mulm kriechen sie, indem sie ihren Körper abwechselnd verlängern und verkürzen. Das Vorderende kann sehr in die Länge estreckt werden und wird beim Berühren von Fremdkörpern itzschnell zurückgezogen, kann aber nicht eingestülpt werden.

The Geographical Distribution of the Acarine Family Oribatidae.

By C. Warburton, M.A., Christ's College.

[*Read* 4 May 1908.]

The Oribatidae are minute free-living Acarines, rarely attaining a millimetre in length, and inhabiting moss and vegetable débris or living on or under the bark of trees. They are vegetable feeders, not eating the moss or the bark itself, but apparently browsing on the microscopic fungoid growths they find in such situations. They also eat pollen.

Very few naturalists have devoted attention to this group and their investigations have practically been limited to the places they themselves have visited, for the creatures are too small to attract the attention of the general collector and are only obtained in any numbers if deliberately searched for. Mr A. D. Michael was the first in this country to take up the study seriously; a few Continental Arachnologists have investigated the Oribatid fauna of their own countries, and one or two American naturalists have described several species without, apparently, paying much attention to previously described European forms. Only in certain restricted regions, therefore, and in them by no means exhaustively have the Oribatidae been hitherto investigated.

Eighteen months ago, in a paper communicated to this Society by Mr N. D. F. Pearce and the present writer, attention was called to the fact that it was possible to transport moss or other material in hermetically sealed tins from very distant localities without injury to any living Oribatidae it might contain, if only the material were not in too dry a condition when collected, so that if anyone could be induced to undertake the small amount of trouble involved in gathering and transmitting moss from suitable localities the examination of its contents might be postponed till its arrival in England. Our eventual knowledge of Oribatid distribution seemed likely, by this means, to become very extensive indeed.

Now there appeared to me reasons for anticipating that the Oribatid fauna of widely separated localities would be highly characteristic, and that this group was extremely well adapted for affording indications of the correctness or otherwise of the accepted zoological regions. In the first place, whether or not the Acarina be a primitive group, it is impossible to consider the Oribatidae a primitive family of the Acarina. On the contrary they appear to be among the most highly differentiated of the mites. Again they do not appear to possess any of the facilities for extensive distribution exhibited by certain other Arachnid groups. The

are not parasitic on animals like the Ixodidae and Sarcoptidae, nor have they any stage similar to the "hypopial nymph" of the Tyroglyphidae for the purpose of temporary attachment to insects, nor can they travel by balloons of their own spinning like many of the spiders. Moreover they do not infest houses or food-stuffs or merchandise, and are not at all likely to be conveyed by ships. Indeed, if the moss is collected well away from human dwellings, in the bush or the jungle, there can be no question of the casual introduction of creatures so small and so slow moving. Finally, their very local distribution in England seemed to indicate that they are slow to spread to new areas.

The adult mites are certainly tenacious of life and not easily killed; yet they are difficult creatures to rear in captivity because the larvae and nymphs always die unless the degree of moisture in their cells is carefully regulated.

We have not yet carried the experiment of importing moss very far, and a few consignments have been quite useless, either because the moss was collected too dry or because the senders were so zealous as to saturate it with formalin for its better preservation, but the few localities from which satisfactory material—or at least material containing some living mites—has been received are so widely scattered that the results are interesting, comprising as they do: The Sikkim Himalaya at an altitude of about 6000 ft.; Madagascar; S. Nigeria; Uganda; Madeira; Canada; British Guiana. We have also examined a few Oribatidae received by Dr Sharp from Hawaii. It may be said at once that the results were not at all what was anticipated. There was a remarkable similarity in the mites wherever they came from, and greatly aberrant forms were distinctly rare. From all localities there were specimens indistinguishable from well known British species, and most of such as were new were closely allied to those already known. Take the case of the Himalaya material, upon which Mr N. D. F. Pearce has reported in a paper in the *Journal of the Royal Microscopical Society* (1906, p. 269). It was found to contain twenty species, distributed among twelve genera, and twelve of these species were British. It was only found necessary to create one new genus, *Chaunoproctus*, to include two species not very remarkable, but somewhat intermediate between the two existing genera *Cepheus* and *Tegeocranus*. Now in view of the fact that there is not, as far as I am aware, a single spider common to England and India, this result was surely somewhat astonishing.

The British species from the Himalaya were:

Pelops acromios, Oribata ovalis, O. alata, Cepheus ocellatus, Liacarus palmicinctus, Notaspis tibialis, N. similis, Tegeocranus latus, Hermannia convexa, H. bistriata, Cymbaeremeus cymba, Nothrus tectorum.

From the other localities the following British forms were obtained:

Madagascar	...	*Oribata alata.*
S. Nigeria	...	*Oribata alata, O. lucasii, O. cuspidata, Hoploderma magnum, Notaspis clavipectinata* (or a variety of it).
Uganda...	...	*Oribata alata, Tegeocranus velatus, Scutovertex sculptus* (or a variety of it).
Madeira	...	*Hermannia nanus, H. bistriata, Notaspis exilis, N. clavipectinata, N. maculosa*[1] and others.
Canada...	...	*Oribata alata, O. quadricornuta, Carabodes marginatus, Tegeocranus velatus, Hermannia arrecta.*
British Guiana...		*Oribata alata, O. lucasii, O. cuspidata, Tegeocranus velatus,* and forms so close to the following species as to be at all events no more than varieties: *O. globula, Liacarus palmicinctus, Hoploderma magnum, Nothrus monodactylus, Carabodes labyrinthicus.*
Hawaii...	...	*Oribata alata, O. globula, O. ovalis, Notaspis lucorum* and *Hoploderma dasypus* (or a variety of it).

Several of the consignments of moss contained disappointingly little life, being, perhaps, not very well selected. The richest was one of the parcels received from British Guiana, and here there were certainly many new species. Only very few, however, were at all striking, most of them differing from British species chiefly in being more highly chitinised and tending to develop excrescences. The resemblances, here as in the other cases, were more striking than the differences.

Another point is worth remarking. The most cosmopolitan of the Oribatidae are neither the most primitive (to all appearance) nor the most active. The genus *Oribata* is apparently the most specialised of the Oribatidae, and seems also to be the most widely distributed, *O. alata* being the most cosmopolitan of all. *Nothrus* has all the appearance of a primitive genus, as its adults often resemble the larvae of *Oribata*, but we have only obtained one British species from the localities in question. Hardly any representatives of the large, long-legged, active mites of the genus *Damaeus* have been received from abroad, and the only known jumping Oribatid, *Zetorchestes*, common on the Continent, has not even made its way to England.

[1] First described by Warburton and Pearce from Nine Wells, Cambridge. Since then a single specimen was received from Ireland, and now it appears from Madeira.

The Formation of γ-Pyrone Compounds from Acetylenic Acids. By S. Ruhemann, M.A., Gonville and Caius College.

[*Read* 9 March 1908.]

The author has shown before that, in the presence of sodium ethoxide, the esters of acetylenic acids condense with β-ketonic esters or β-diketones to form α-pyrone derivatives which, under the influence of ammonia, were transformed into members of the pyridine group. He has found, now, that the esters of acetylenic acids react with ketones with the grouping $.CH_2.CO.$ to yield γ-pyrone compounds. Up to the present this reaction has been applied to the formation of diphenyl γ-pyrone and phenyl-methyl γ-pyrone by using, on the one hand, ethyl phenyl propiolate, on the other, acetophenone and acetone respectively.

The Action of Mustard Oils on the Ethyl Esters of Malonic and Cyanoacetic Acids. By S. Ruhemann, M.A., Gonville and Caius College.

[*Read* 9 March 1908.]

This research had been undertaken with the view of arriving at an explanation of certain results at which the author arrived in the course of his studies on Thioxanthoxalanil.

Thiocarbimides, i.e. phenyl thiocarbimide unites with ethyl sodiomalonate to form an additive product which, with acids, yields ethyl thiocarbanilinomalonate. This ester is yellow, whereas its metallic salts as well as its benzyl derivative are colourless. Phenyl thiocarbimide also combines with ethyl sodiocyanoacetate and furnishes an additive product which is colourless, as indeed are its salts and benzyl derivative, but at 100° C. or on crystallisation from hot solvents turns yellow. This behaviour points to the existence of the substance in two tautomeric forms.

The action of ethyl chloroacetate on the additive products, mentioned above, yields cyclic compounds which are to be regarded as derivatives of tetra-hydro-thiophene. These substances are yellow but, under the influence of caustic potash, change into colourless isomerides.

On the formation of lactic acid and carbonic acid during muscular contraction and rigor mortis. By P. W. Latham, M.D., Gonville and Caius College.

[*Read* 9 March 1908.]

(*Abstract.*)

By combining prussic acid with pyruvic acid $CH_3 . CO . COOH$ and subsequent hydrolysis methyl-tartronic acid

$$CH_3 . C(OH) . (COOH)_2$$

is produced. When decomposed this acid is resolved exactly into lactic acid $CH_3 . CH(OH) . COOH$ and CO_2. Dr Latham suggested that the nitrile of this acid $CH_3 . C(OH) . (CN)_2$, which by hydrolysis is resolved into lactic acid, CO_2 and $2NH_3$ formed one of the constituents of proteid matter, and that during muscular contraction the NH_3 combined with other constituents, the lactic acid and CO_2 being alone set free. He supported this hypothesis by showing how, in the earliest stages in the genesis of organic matter in plants, this substance can be formed from acetic anhydride and prussic acid

$$(CH_3 . CO)_2 . O \rightarrow 2CH_3 . CO . CN \rightarrow 2CH_3 . C(OH) . (CN)_2$$

which when combined with NH_3 forms amino-iso-succinic nitrile $CH_3 . C(NH_2) . (CN)_2$. The latter by hydrolysis being resolved into $CH_3 . C(NH_2) . (COOH)_2 + 2NH_3$ or into α-alanine

$$CH_3 . CH(NH_2) . COOH$$

and urea $CO\begin{matrix}\diagup NH_2 \\ \diagdown NH_2\end{matrix}$ the latter being resolved into $CO_2 + 2NH_3$.

He then pointed out that Schutzenberger (*Comptes Rendus*, t. 80, p. 232), in his earliest experiments on the decomposition of albumin, obtained among other products an isomeride of aspartic acid, $C_4H_7NO_4$, differing from it, however, in being highly soluble in water. It was now suggested that this compound was iso-aspartic acid $CH_3 . C(NH_2) . (COOH)_2$ arising, as shown above, from $CH_3 . C(OH) . (CN)_2$. Another substance obtained by Schutzenberger "gave numbers corresponding to di-amino-citric acid" $C_6H_{11}N_2O_6$. It was suggested that this formula should be $C_6H_{12}N_2O_6$; in which case it was a compound of glycocoll

$$CH_2 . (NH_2) . COOH,$$

and the above-mentioned iso-aspartic acid; these two substances being derived respectively from amino-malonic nitrile, and methyl tartronic nitrile, which therefore must be regarded as constituents of the living proteid molecule.

On the complete hydrolytic decomposition of egg-albumin at 180° C.; *and on the constitution and synthesis of dead and living albumin.* By P. W. Latham, M.D., Gonville and Caius College.

[*Read* 9 March 1908.]

(*Abstract.*)

That lactic acid and carbonic acid can be formed in the manner above indicated, at once suggests that other proteid derivatives may be synthesised from pyruvic acid and its homologues or their nitriles. A very slight investigation demonstrates the truth of this assumption and shows that the ketonic acids occupy a most important place in the formation or synthesis of various proteid derivatives. Picoline, pyridine, indole, the chinoline carboxylates, xR-chinolines, tyroleucine etc. etc. are some examples. The most important deduction, however, is that the **imino-ketonic acids** are the compounds Schutzenberger termed Leucéins, "a knowledge of the constitution of which" was in his opinion "the only thing wanting to solve the problem as to the general structure of proteid matter." These leucéins differ in composition from the amino fatty acids simply by two atoms of hydrogen, the compounds $C_3H_5NO_2$, $C_4H_7NO_2$, $C_5H_9NO_2$, $C_6H_{11}NO_2$ being respectively

$$CH_3 . C(NH) . COOH,$$

$$CH_3 . C(NH) . CH_2 . COOH,$$

$$CH_3 . C(NH) . CH(CH_3) . COOH$$

and $$CH_3 . C(NH) . CH(C_2H_5) . COOH.$$

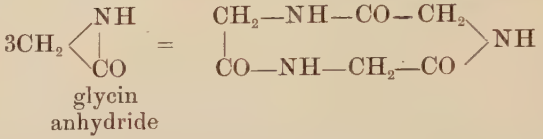
These combined with the respective amino fatty acids constitute Schutzenberger's gluco-proteins $C_6H_{12}N_2O_4$ and generally

$$C_nH_{2n}N_2O_4.$$

A printed table (Table I), based upon these data, was laid before the Society, showing the complete resolution into its components of Schutzenberger's "residu fixe," $C_{221}H_{435}N_{49}O_{105}$, and of its constituents $3C_9H_{16}N_2O_6$, acids amidés forts; $3C_9H_{20}N_2O_4$, leucines; and $2C_7H_{14}N_2O_4 + 16C_9H_{18}N_2O_4$, gluco-proteins. (*Annales de Chimie et Physique*, t. XVI. p. 398 (1879).)

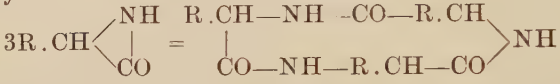
In 1887 Dr Latham in his Croonian lectures and again in 1897

suggested that in dead proteid the antecedents of the amino fatty acids are their anhydrides, a triple union of each taking place

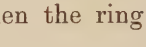


glycin anhydride

or generally

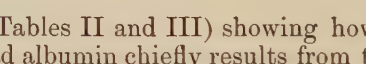


compounds which, when the ring is broken, are now known as polypeptides.

Further, in accordance with Pflüger's view that ammonium cyanate is the type of living and urea of dead nitrogen, he suggested that when  in the above triple molecule becomes part of living tissue it is transformed into the cyan-alcohol .

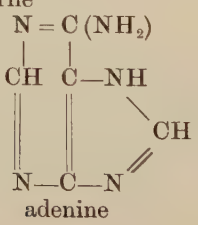
Printed tables (Tables II and III) showing how on these data the synthesis of dead albumin chiefly results from the combination of the polypeptides with the imino-ketonic acids, and how the synthesis of living albumin chiefly results from the combination of the cyan-alcohols with the imino-ketonic acids, were laid before the Society.

Finally, Dr Latham advanced the view that the phenomena of the coagulation of the blood are associated with the transformation of

(i) 

(ii) $CH(NH_2).(CN)_2 + 2HCN$ into

amino-malonic nitrile



adenine

TABLE I.

THE COMPLETE HYDROLYTIC DECOMPOSITION OF EGG ALBUMIN WITH BARIUM HYDRATE AT 180° C.

(i)	(ii)	(iii)	(iv)	(v)	(vi)
16 NH_3	$C_6H_4(OH).CH_2.CH(NH_2).COOH$ tyrosine	$CH(NH_2).COOH$ | $CH_2.CH_2.COOH$ glutamic acid			3 $CH_3.(CH_2)_3.CH(NH_2).COOH$ *a* amino-caproic acid
+4 $(COOH)_2$ oxalic acid			3 $CH_3.(CH_2)_2.CH(NH_2).COOH$ *a* amino-valerianic acid		3 $CH_3.(CH_2)_2.CH(NH_2).COOH$ *a* amino-valerianic acid
+3 CO_2		$CH(NH_2).COOH$ | $CH_2.COOH$ aspartic acid	3 $CH_3.CH_2.CH(NH_2).COOH$ *a* amino-butyric acid		9 $CH_3.CH_2.CH(NH_2).COOH$ *a* amino-butyric acid
+4 $CH_3.COOH$ acetic acid				2 $CH_3.CH(NH_2).COOH$ *a* amino-propionic acid	$CH_3.CH(NH_2).COOH$ *a* amino-propionic acid
$+S+2SH_2+H_6$		$CH(NH_2).COOH$ | $COOH$ amino-malonic acid			
		$CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid			3 $CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid
		$CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid			3 $CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid
		$CH_3.C(NH)CH_2.COOH$ imino-acetyl-acetic acid		2 $CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid	9 $CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid
					$CH_3.C(NH).COOH$ imino-pyruvic acid
$C_{19}H_{82}N_{16}O_{30}S_3$ Schutzenberger's polynomial with H_{10} added	$C_9H_{11}NO_3$ tyrosine	$C_{27}H_{48}N_6O_{18}$ or 3 $C_9H_{16}N_2O_6$ acids amidés forts	$C_{27}H_{60}N_6O_{12}$ or 3 $C_9H_{20}N_2O_4$ leucines	$C_{14}H_{28}N_4O_8$ or 2 $C_7H_{14}N_2O_4$ gluco-proteins	$C_{144}H_{288}N_{32}O_{64}$ or 16 $C_9H_{18}N_2O_4$
			$C_{221}H_{435}N_{49}O_{105}$ résidu fixe		
$C_{240}H_{517}N_{65}O_{135}S_3$ or $C_{240}H_{397}N_{65}O_{75}S_3+60\ H_2O$ albumin					

TABLE II.

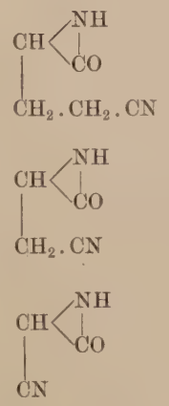
COMPOSITION OF LIVING ALBUMIN.

(i)	(ii)	(iii)	(iv)	(v)	(vi)
3 HCN	$(NH_2)C_6H_4.CHO$ amido-benzaldehyde	$CH(OH).CN$ $\vert$ $CH_2.CH_2.CN$ oxy-glutaric nitrile			$3\,CH_3.(CH_2)_3.CH\langle^{OH}_{CN}$ pentene cyan-alcohol
3 CNHS thio-cyanic acid	$CH(NH_2)(CN)_2$ amino malonic nitrile +2 HCN		$3\,CH_3.(CH_2)_2.CH\langle^{OH}_{CN}$ butene cyan-alcohol		$3\,CH_3.(CH_2)_2.CH\langle^{OH}_{CN}$ butene cyan-alcohol
$(CH_3.CO)_2O$ acetic anhydride		$CH(OH).CN$ $\vert$ $CH_2.CN$ malic or oxy-succinic nitrile	$3\,CH_3.CH_2.CH\langle^{OH}_{CN}$ propylidene cyan-alcohol		$9\,CH_3.CH_2.CH\langle^{OH}_{CN}$ propylidene cyan-alcohol
$(CH_3.CO.CN)_2$ diacetyl-dicyanide		$CH(OH).CN$ $\vert$ CN tartronic, or oxy-malonic nitrile		$2\,CH_3.CH\langle^{OH}_{CN}$ ethylidene cyan-alcohol	$CH_3.CH\langle^{OH}_{CN}$ ethylidene cyan-alcohol
		$CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid			$3\,CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid
		$CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid			$3\,CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid
		$CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid		$2\,CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid	$9\,CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid
					$CH_3.C(NH).COOH$ imino-pyruvic acid

$C_{16}H_{18}N_8O_5S_3$	+	$C_{12}H_{12}N_6O$	+	$C_{27}H_{39}N_9O_9$	+	$C_{27}H_{48}N_6O_6$	+	$C_{14}H_{24}N_4O_6$	+	$C_{144}H_{256}N_{32}O_{48}$	=	$C_{240}H_{397}N_{65}O_{75}S_3$
+		+		+		+		+		+		+
$19\,H_2O$	+	$8\,H_2O$	+	$9\,H_2O$	+	$6\,H_2O$	+	$2\,H_2O$	+	$16\,H_2O$	=	$60\,H_2O$
↓		↓		↓		↓		↓		↓		↓
$C_{16}H_{56}N_8O_{24}S_3$	+	$C_{12}H_{28}N_6O_9$	+	$C_{27}H_{57}N_9O_{18}$	+	$C_{27}H_{60}N_6O_{12}$	+	$C_{14}H_{28}N_4O_8$	+	$C_{144}H_{288}N_{32}O_{64}$	=	$C_{240}H_{517}N_{65}O_{75}S_3$

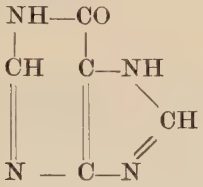
TABLE III.

COMPOSITION OF **DEAD** ALBUMIN.

(i)	(ii)	(iii)	(iv)	(v)	(vi)
2 HCN $(HCN)_2S_3$ persulphocyanic acid $(CH_3.CO)_2O$ acetic anhydride $2\,CH_3.C(NH)(CO)(CN)$	$(NH_2)C_6H_4.CHO$ amido-benzaldehyde $N{=}C(NH_2)$, C, NH, C $+2HCN$ or $N{=}C(NH_2)$, CH, $C{-}NH$, CH, $N{-}C{-}N$ adenine	 $CH_2.CH_2.CN$ $CH_2.CN$ CN	$3\,CH_3.(CH_2)_2CH(NH)(CO)$ amino-valerianic anhydride $3\,CH_3.CH_2.CH(NH)(CO)$ amino-butyric anhydride	$2\,CH_3.CH(NH)(CO)$ amino-propionic anhydride	$3\,CH_3.(CH_2)_3.CH(NH)(CO)$ amino-caproic anhydride $3\,CH_3.(CH_2)_2.CH(NH)(CO)$ amino-valerianic anhydride $9\,CH_3.CH_2.CH(NH)(CO)$ amino-butyric anhydride $CH_3.CH(NH)(CO)$ amino-propionic anhydride
		$CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid $CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid $CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid		$2\,CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid	$3CH_3.C(NH).CH(C_2H_5).COOH$ imino-ethyl-acetyl-acetic acid $3\,CH_3.C(NH).CH(CH_3).COOH$ imino-methyl-acetyl-acetic acid $9\,CH_3.C(NH).CH_2.COOH$ imino-acetyl-acetic acid $CH_3.C(NH).COOH$ imino-pyruvic acid

$C_{16}H_{18}N_8O_5S_3$	+	$C_{12}H_{12}N_6O$	+	$C_{27}H_{39}N_9O_9$	+	$C_{27}H_{48}N_6O_6$	+	$C_{14}H_{24}N_4O_6$	+	$C_{144}H_{256}N_{32}O_{48}$	$= C_{240}H_{397}N_{65}O_{75}S_3$
$+19\,H_2O$		$+8\,H_2O$		$+9\,H_2O$		$+6\,H_2O$		$+2\,H_2O$		$+16\,H_2O$	$= 60\,H_2O$
↓		↓		↓		↓		↓		↓	↓
$C_{16}H_{56}N_8O_{24}S_3$	+	$C_{12}H_{28}N_6O_9$	+	$C_{27}H_{57}N_9O_{18}$	+	$C_{27}H_{60}N_6O_{12}$	+	$C_{14}H_{28}N_4O_8$	+	$C_{144}H_{288}N_{32}O_{64}$	$= C_{240}H_{517}N_{65}O_{75}S_3$

(iii) $CH(OH).(CN)_2 + 2HCN$ into
tartronic nitrile



hypoxanthine

(iv) *ortho*-$NH_2.C_6H_4.CHO$ into the para form, and

(v) the conversion of 3HCNS into
$HCN + (HCN)_2S_3$.

The nature of the γ rays. By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Experimental Physics.

[*Read* 10 February 1908.]

Two views have been advanced as to the nature of the γ rays. One that they are pulses of electromagnetic disturbance propagated through the ether, the other that they are doublets made up of a positive and negative charge, travelling with great velocity and possessing energy and momentum. There is thus much the same difference between these theories as between the undulatory and emission theory of light. The two theories approximate closely to each other, if we suppose, as the author has suggested, that the electromagnetic disturbance in the pulse is not distributed uniformly over the wave front but is concentrated in patches, as in each of these patches there are electric and magnetic forces, the patches will have energy and momentum in the direction in which the rays are propagated, the patches thus resemble the doublets in many of their properties. The two theories would be differentiated (1) by the velocity of propagation of the rays which on the pulse theory would be that of light and on the doublet theory might be anything, and (2) by the polarization in the secondary rays produced when the primary rays come into contact with matter. Professor Barkla's experiments show that this polarization is in accordance with the pulse theory, and such investigations as have been made on the velocity of propagation indicate that this is equal to that of light.

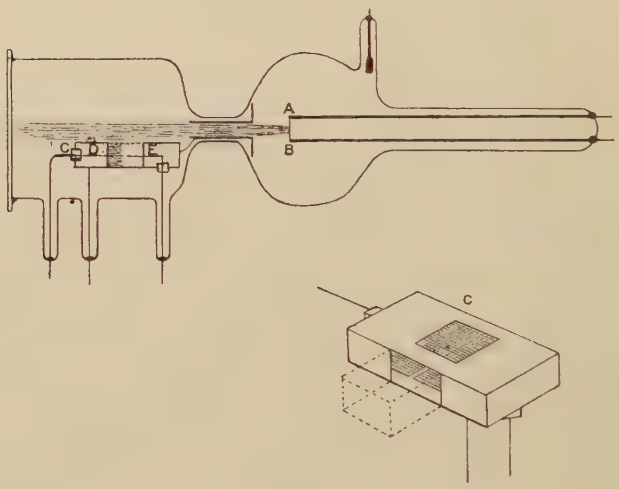
On the velocity of Secondary Cathode Rays from gases. By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Experimental Physics.

[*Read* 10 February 1908.]

When a discharge passes from a Wehnelt cathode, on which the lime is concentrated in a small patch, the clearly defined blue pencil of cathode rays emanating from the lime is seen to be surrounded by a bluish haze which may, under favourable circumstances, fill the vacuum tube. This haze is due to secondary cathode rays produced by the impact of the primary cathode rays against the molecules of the gas in the vacuum tube. That this is the case may be shown by placing a piece of metal in the tube; when the metal is uncharged the haze will extend right up to it, but if the metal is charged in such a way that the electric force in its neighbourhood tends to repel a negative particle from it, then it will be found that if the force exceeds a very moderate value, the haze will be repelled from the metal and there will be a very well defined dark space round the metal, the thickness of the dark space increasing with the charge on the metal. If however the metal is charged so that the electric force in its neighbourhood acts so as to attract a negatively electrified particle there is no dark space round the metal, the haze comes into contact with it and no diminution in luminosity is perceptible.

It is evident that if we measure the electric field in the neighbourhood of the metal when this is surrounded by the dark space we can calculate the difference of potential required to stop the negative particles which produce the haze and hence determine the velocity with which they are projected from the molecules of gas struck by the primary cathode rays. The method employed to do this is represented in Fig. 1. A pencil of cathode rays starting from the lime covered cathode A, passed through an aperture and then close over the top of the box C. At the top of the box there

was a window made of wire gauze and in the middle of the box, insulated from it, was a horizontal piece of wire gauze divided into two pieces D and E which were insulated from each other. Electrodes came from the box and from the two pieces of gauze to the outside of the tube. A window formed of a piece of tube in the side of the box allowed observations of the luminosity in the box to be made from the outside. The distance between the top and bottom of the box was 7 mm. When the cathode rays passed the gauze at the top, the bluish haze spread through the box, filling it with uniform luminosity. If the sides of the box were connected to the positive pole of a battery and the gauze to the negative pole, the negative particles sent through the window



at the top were acted upon by a force tending to stop them, and if the potential difference between the gauze and the top of the box exceeded a certain value, the luminosity instead of filling the box stopped short of the gauze and was confined to a layer at the top of the box, the thickness of this layer diminishing as the potential difference between the gauze and the box increased. If the particles lost their power of producing luminosity long before being stopped, so that some of them travelled through the dark space at the top of the box, then the electric field below the gauze would increase their energy, restoring to the particles the energy lost in the upper part of the box, and the luminosity ought to appear again against the lower surface of the box.

A comparatively small difference of potential, say 4 or 5 volts, was sufficient to produce a marked diminution in the brightness of the luminosity just above the gauze without destroying it altogether, the appearance showed that the particles emitted under the action of the primary rays did not all pass through the top of the box with the same velocity: the measurements made had for their object the determination of the maximum velocity with which the secondary cathode rays were emitted, or rather the maximum velocity possessed by a number sufficiently large to produce an appreciable effect upon the luminosity. The method adopted was as follows: between one half, D, of the gauze and the box a large potential difference was established, so large that it stopped all the secondary cathode particles before they reached the gauze; that it was sufficient to do this was ascertained by still further increasing the potential and observing that there was no further diminution in the luminosity below the gauze: there was always a just perceptible luminosity in this region due to the light from the discharge in the tube coming through the window at the top of the box. The potential between E, the other half of the gauze, and the box, which at the beginning of the experiment was the same as that between D and the box, was gradually diminished until the luminosity below the gauze E was appreciably greater than that below D, indicating that some particles were projected with enough energy to surmount the potential difference between the box and E. To facilitate the determination of the point where the increase of luminosity began, a switch was inserted so that the potentials of D and E could rapidly be interchanged; it was found easier to be sure of difference of luminosity when the light and dark parts could be rapidly interchanged than when they kept always to one side. The method has also the advantage of eliminating the effect of any irregularities in the distribution of light over the window at the top of the box.

The results of the experiments with the lime covered cathode are given in the following table; the first column contains the potential difference in volts between the lime covered cathode and the anode in the discharge tube, the second the greatest potential difference between the gauze and the walls of the box which allowed any luminosity to penetrate below the gauze. This potential difference multiplied by the charge on a corpuscle gives the greatest kinetic energy with which the secondary cathode rays are projected from the molecules of the gas when struck by the primary cathode rays emitted by the lime cathode, or more strictly the greatest kinetic energy of the secondary rays which are emitted in sufficient numbers to produce appreciable luminosity in the gas through which they pass.

Potential difference in volts in discharge tube	Potential difference required to stop the secondary rays
150	42
110	41
90	40
85	44
70	40
50	44
42	42
35	42
32	39
27	40

We see from this that the energy of the secondary rays is independent of the energy of the primary rays. To test this point still further the lime covered cathode was replaced by an aluminium cathode, and the primary cathode rays produced by the discharge of an induction coil. The potential difference in this case being many thousand volts, the experiments were tried at several pressures: when the pressure was so low that the walls of the tube were covered with green phosphorescence, the voltage required to stop the secondary rays was 41 volts; when the pressure was higher so that the dark space round the cathode was about 1 cm. the corresponding voltage was 43; when the pressure was higher and the dark space 4 mm., the corresponding voltage was 42. Thus the energy of the secondary rays produced by the high potential discharge of an induction coil is the same as that of the rays produced by the low potential discharge from a lime cathode. If we take 40 volts as the measure of the voltage required to stop the secondary rays, the velocity with which these are projected is $3{\cdot}7 \times 10^8$ cm./sec. Füchtbauer (*Phys. Zeits.* VII. p. 748, 1906) gives $3{\cdot}3 \times 10^8$ cm./sec. as the velocity of secondary cathode rays emitted when Canal-Strahlen or rapid cathode rays fall on a metal plate. An inspection of the results given above shows that in some cases the velocity of the secondary rays is greater than that of the primary rays producing them. Thus when the potential difference for the primary rays was only 27 volts, it required a potential difference of 40 volts to stop the secondary rays.

This result seems strongly to support the view that the energy in the secondary rays is determined by the atoms emitting them and not by the energy of the primary rays. It is a very remarkable fact that the velocity with which these secondary rays are emitted does not seem to vary much with the nature of the atoms emitting them; thus Füchtbauer (*loc. cit.*) found that the velocity of the secondary rays from metals is $3{\cdot}3 \times 10^8$ cm./sec., while we have found that the velocity of those emitted by gases (air, hydrogen and carbonic acid were tried and no appreciable difference found

between them) is $3{\cdot}7 \times 10^8$ cm./sec.: the difference between these values is hardly greater than the errors of experiments.

The constancy of the velocity of the corpuscles would be attained if the primary rays were to detach in the first instance from the molecules of the gas, not a corpuscle, but a more complex system, say for example a doublet containing a corpuscle and a positively charged particle, the two constituents of the doublet rotating rapidly round each other. If this doublet were subsequently to be broken up, the corpuscle flying off with the velocity due to its rotation in the doublet, and if similar doublets came from the molecules of different gases, the velocity of the secondary cathode rays would be independent of the nature of the gas as well as of the intensity of the rays.

I wish to acknowledge the great help I have received from Mr G. W. C. Kaye, of Trinity College, in carrying out this investigation.

Relation between the Geographical Distribution and the classification of the Onychophora. By A. Sedgwick, M.A., Professor of Zoology and Comparative Anatomy.

[*Read* 24 February 1908.]

(*Abstract.*)

The Onychophora comprise the single genus *Peripatus* which was discovered in St Vincent in the Antilles in 1826. Later, specimens of it were obtained from South Africa and Australasia, and its arthropodan nature was established by Moseley in 1874. In 1888 it was shewn by the author of the present communication that the species of it fell into discontinuous groups, all capable of precise definition. At present seven such groups are known, each occurring in a definite geographical area. These have been exalted to the rank of genera and grouped in families, but the author thinks that it is inadvisable to take this step at the present time. The geographical groups, together with the names which have been applied to them by the author, are as follows:

(1) Neo-Peripatus from the neotropical region as far south as Rio de Janeiro.

(2) Congo-Peripatus from the Congo district in Africa.

(3) Eo-Peripatus from Malaya (Malacca and Sumatra).

(4) Capo-Peripatus from South Africa (Natal to Cape Town).

(5) Melano-Peripatus from New Britain.

(6) Austro-Peripatus from Australia, Tasmania and New Zealand.

(7) Chilio-Peripatus from Chili.

The author shewed (1) that these geographical groups of species are natural zoological groups, the members of which are more closely allied to each other than to those of the other groups; (2) that the distinguishing specific characters are distributed in an entirely haphazard manner among the different specific groups, so that it is quite impossible to shew their phylogenetic affinities by any tree-like arrangement.

PROCEEDINGS

OF THE

Cambridge Philosophical Society.

Some Reactions of Phenyliodide Chloride and Iodosobenzene Acetate. By HERBERT HENRY HODGSON, M.A., Ph.D., B.Sc., Trinity College. (Communicated by H. O. JONES, M.A., Clare College.)

[*Read* 18 May 1908.]

The aromatic iodides possess the noteworthy property of combining with two atoms of chlorine, the iodine previously univalent becoming trivalent. Thus phenyl iodide combines additively with chlorine to form phenyliodide chloride (I. pr. 23·154; B. 25·3494; 26·357, 25·2632).

$$C_6H_5I + Cl_2 = C_6H_5ICl_2.$$

From phenyliodide chloride a further series of remarkable bodies was obtained by Willgerodt in 1886, known as iodoso-benzene, iodo-benzene, diphenyliodonium iodide and diphenyliodonium hydroxide, in which the iodine is trivalent.

Inorganic chemistry provides us with bodies like ICl_3, in which the trivalent attitude of iodine is manifest.

Further, the iodoso compounds have the power of uniting with acids to form salts, in which they act like a di-acid base; e.g.

$$C_6H_5—I\begin{matrix}OH\\OH\end{matrix}$$

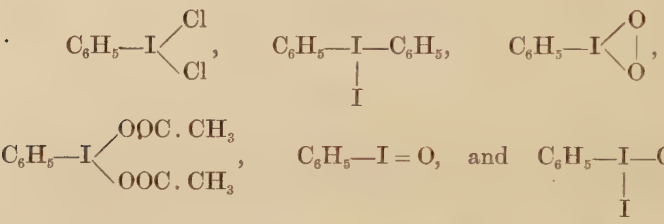
An example of this property is afforded in the formation of iodoso-benzene acetate, by the action of glacial acetic acid on iodoso-benzene.

$$C_6H_5IO + \begin{matrix}CH_3.COOH\\CH_3.COOH\end{matrix} = C_6H_5—I\begin{matrix}OOC.CH\\OOC.CH\end{matrix} + H_2O$$

At the suggestion of Mr H. O. Jones, the author has investigated a series of reactions with the object of finding whether

compounds could be formed in which the above characteristic property would be extended.

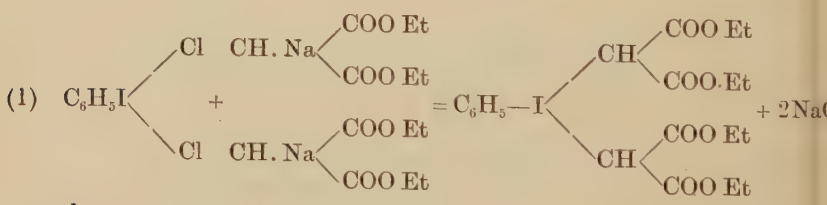
An examination of the compounds



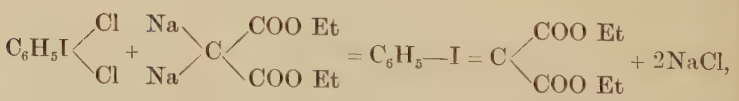
shows that the trivalent iodine is combined in all cases with univalent radicles, except in that of iodoso-benzene in which the iodine is united with the oxygen by means of a double bond.

Experiments were therefore undertaken to ascertain whether compounds could be formed in which iodine was united to carbon by means of a double bond. To attain this end, the action of phenyliodide chloride on the sodium compounds of malonic ester and cyanacetic ester, and also the action of iodoso-benzene acetate on the same esters, were studied.

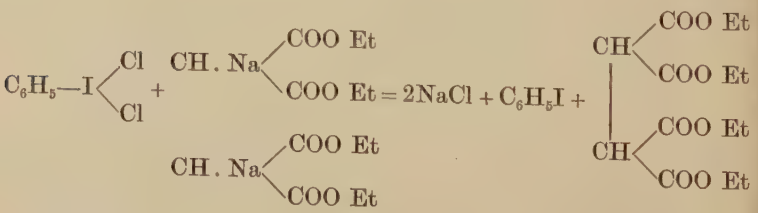
Malonic ester forms two sodium compounds when the theoretical quantities of sodium wire are added to solutions of malonic ester in absolute alcohol. The action of these sodium derivatives with phenyliodide chloride may take place theoretically in two different ways, viz.:



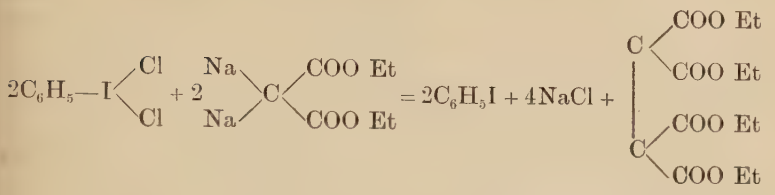
and



or (2)



and



Should the second of these reactions take place, then the action of phenyliodide chloride is exactly analogous with that of iodine on the sodium compounds of malonic ester as found by Bischoff and Rach (B. 17·2781; B. 29·1290; B. 32·860).

The experiments were performed both at ordinary temperatures and at the temperature of the boiling water-bath. In each case the reactions appeared to go in the same way, although more readily at the higher temperatures.

The attempt to isolate bodies in which the iodine was trivalent, proved futile, although the methods of separation employed may account for the failure of the experiments.

Three methods of separation were tried: the first being the fractional distillation of the reaction mixture under reduced pressure, after filtering off the precipitate formed; the second being to pass steam through the reaction mixture and then to extract the residue with ether; and the third was to extract the cold reaction mixture with ether.

The results of these three methods were as follows:

(1) Three fractions were collected consisting of

(*a*) alcohol and ether,

(*b*) phenyliodide,

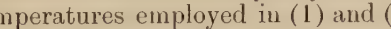
and (*c*) a substance containing no iodine.

Only a small quantity of (*c*) could be collected owing to excessive charring and decomposition taking place.

(2) Phenyliodide distilled over leaving a residue containing no iodine, and

(3) The extract contained much phenyliodide.

The high temperatures employed in (1) and (2) would doubtless tend to affect the decomposition of any substance containing the groupings



or

but the third method proved also that at ordinary temperatures phenyliodide was formed, so that the reactions under the con-

ditions employed evidently tend to take place in the second way depicted above.

The same experiments were performed with iodoso-benzene acetate and similar results established, although the yields were better than when using phenyliodide chloride.

The same experiments were also performed using diphenyl-iodonium iodide, both at ordinary temperatures and by heating for several hours on the boiling water-bath, but in this case no chemical reaction appeared to take place.

The reactions proceeded in exactly the same manner when sodium cyanacetic ester was acted on by phenyliodide chloride and by iodoso-benzene acetate, phenyliodide being produced and dicyansuccinic ester formed as follows:

$$C_6H_5—I\begin{matrix}Cl\\Cl\end{matrix} + \begin{matrix}CH.Na.CN.COO\,Et\\CH.Na.CN.COO\,Et\end{matrix} = C_6H_5I + 2NaCl + \begin{matrix}CH.CN.COO\\|\\CH.CN.COO\end{matrix}$$

and

$$C_6H_5—I\begin{matrix}OOC.CH_3\\OOC.CH_3\end{matrix} + \begin{matrix}CH.Na.CN.COO\,Et\\CH.Na.CN.COO\,Et\end{matrix} = C_6H_5I + 2CH_3.COO\,N + \begin{matrix}CH.CN.COO\,Et\\|\\CH.CN.COO\,Et\end{matrix}$$

Experimental.

The phenyliodide chloride was prepared by passing chlorine into a mixture of phenyliodide dissolved in five times its volume of chloroform, and cooled by ice-water. The yellow needles which separated were well washed on a filter-paper with pure chloroform, and allowed to dry in the air on a pad of filter-paper.

Action of phenyliodide chloride on mono-sodium malonic ester.

(*a*) *At ordinary temperatures.*

Mono-sodium malonic ester was prepared by dissolving 2·51 grams of sodium wire in absolute alcohol, and then adding 17·45 grams of malonic ester to the solution. After standing a short time, dry ether was added to the mixture until turbidity just commenced, 15 grams of $C_6H_5ICl_2$ were then added gradually and the mixture well shaken; heat was developed and moderated by cooling the vessel. The mixture was allowed to stand for a day and then the alcohol and ether distilled off at ordinary atmospheric pressure.

On raising the temperature, phenyliodide distilled over be-

tween 185°—190°. Further elevation of temperature caused only decomposition and charring to take place.

(*b*) The experiment was repeated using the same quantities of material, and after distilling off the alcohol and ether at ordinary temperatures the residue was distilled in vacuo, three fractions being collected:

(1) at ordinary temperatures consisting of alcohol and ether;

(2) at the temperature of boiling water consisting of phenyliodide

and (3) using the naked flame, when charring took place and a colourless liquid distilled over and solidified in the receiver.

This was re-distilled in vacuo and gave a solid melting at 76° C.

Melting point of ethane-tetracarboxylic ester = 76° C.

The solid was re-crystallised from ether and again gave the melting point 76° C.

On combustion:

·2014 gave ·3884 CO_2 and ·1262 H_2O. C = 52·59 °/₀,
H = 6·96 °/₀.
$C_{14}H_{22}O_8$ requires C = 52·83 °/₀. H = 6·91 °/₀.

(*c*) The experiment was repeated using the same quantities as before, but the reaction-mixture was heated on the water-bath for several hours under a reflux condenser. A better yield of the solid was obtained, and this on re-crystallisation from ether gave the melting point 76° C.

(*d*) The same quantities were again mixed together and heated on the water-bath under a reflux condenser for several hours. Steam was then conducted through the mixture, after the salt had been filtered off and the alcohol and ether distilled from it.

Phenyliodide came over, and on standing for a while the residue in the flask yielded long slender crystalline needles. These on re-crystallisation from ether gave the melting point 76° C.

(*e*) Lastly, the reaction was proceeded with in the cold using the above quantities, distilled water was added to the mixture, and the whole extracted with ether. On allowing the ether to evaporate in the air, phenyliodide remained behind, from which long needles crystallised out and these on re-crystallisation from ether gave a melting point 76° C.

The action of phenyliodide chloride on monosodium malonic ester under the conditions employed thus gives the ethyl ester of ethane tetracarboxylic acid instead of a compound containing trivalent iodine.

Action of phenyliodide chloride on disodium malonic ester.

Disodium malonic ester was prepared by adding to 1·673 grms. of sodium wire dissolved in absolute alcohol, 5·82 grms. of malonic ester. After standing for some time absolute ether was added until turbidity just began to appear. 10 grms. of $C_6H_5ICl_2$ were then added in small quantities at a time and the mixture well shaken. Heat was developed, and this was moderated by cooling the flask. After standing for several days the reaction-mixture was filtered and the coloured precipitate formed was found to contain sodium chloride mixed with phenyliodide. The alcohol and ether were distilled from the solution, and then the whole distilled in vacuo. Phenyliodide came over, and then the whole contents of the flask charred with decomposition, no further distillate collecting.

The experiment was repeated, using the same quantities, and heating the mixture for several hours on the water-bath under a reflux. On filtering the product the precipitate was a pure white containing sodium chloride but no sodium and phenyl-iodides, thus showing that the reaction takes place much better the higher the temperature. On fractional distillation in vacuo only phenyliodide came over, excessive charring taking place as before.

On submitting the precipitates formed in the reaction to continued extraction with hot ether and then evaporating off the ether from the ethereal solution, crystals were deposited, which on re-crystallisation from pure dry ether gave a melting point 76° C. One product of the reaction was therefore the ethyl ester of ethane tetracarboxylic acid.

The same quantities of phenyliodide chloride and disodium malonic ester were mixed together as before, and heated for several hours on the water-bath under a reflux. After filtering, the alcohol and ether were distilled off and the mixture then heated for several hours under a reflux with strong KOH. Steam was afterwards conducted through the saponified solution, and phenyliodide thus got rid of. The residue was then concentrated to a small bulk on the water-bath, and glacial acetic acid added until the solution was just acid. Rectified spirit was then added to the acid liquid, when a greyish white precipitate began to settle down. The mixture was allowed to stand for several days and then filtered. The precipitate was detached from the filter-paper, and boiled with absolute alcohol for a considerable time. Further, the precipitate was dissolved in water, and the substance in solution reprecipitated by absolute alcohol. After filtering, the solid was dried at 100° C. in the air and then in vacuo. The amount of potassium in the solid was estimated by converting a weighed amount of the salt into sulphate. ·2474 of salt gave ·2365 of K_2SO_4. $K = 42{\cdot}85\ ^{\circ}/_{\circ}$.

A combustion of the solid was made mixing it in the boat with freshly ignited $K_2Cr_2O_7$.

·1175 gave ·0854 CO_2 and ·0035 H_2O. C = 20·00 °/₀.
H_2O = 2·31 °/₀.

Now

$C(COOK)_2$
‖ requires K = 43·82 °/₀. H = 0 °/₀ and C = 20·22 °/₀.
$C(COOK)_2$

$C(COOK)_2$
‖ . H_2O requires K = 41·71 °/₀.
$C(COOK)_2$ H = 4·81 °/₀ and C = 19·25 °/₀.

And

$C(COOK)_2$
‖ . $2H_2O$ requires K = 39·79 °/₀.
$C(COOK)_2$ H = 9 18 °/₀ and C = 18·36 °/₀.

Also caustic potash saponifies the ethyl ester of ethane tetracarboxylic acid to ethane tricarboxylic acid, and this again breaks up on continued saponification with potash, therefore the solid obtained cannot be the potassium salt of ethane tetracarboxylic acid. Again, $K_4C_6O_8 . H_2O$ requires 4·81 °/₀ of water, and on combustion of the solid only 2·31 °/₀ was obtained, which can therefore be put down to experimental error and residual moisture in the combustion tube. The solid must therefore be the tetrapotassium salt of ethylene tetracarboxylic acid. This result is in accordance with theory.

The action of disodium-malonic ester on phenyliodide chloride is therefore to form ethane tetracarboxylic ester in small quantities as a bye-product, and mainly ethylene or dicarbon-tetracarboxylic ester. The free acid is very unstable and an attempt to prepare it proved unsuccessful.

The potassium salt was obtained as a very hygroscopic white powder.

Action of iodoso-benzene acetate on monosodium malonic ester.

The iodoso-benzene acetate used was prepared by dissolving iodoso-benzene in a small quantity of glacial acetic acid, evaporating the solution to dryness on the water-bath and after pulverising the solid residue, re-crystallising from benzene. Colourless prisms of

$$C_6H_5—I\begin{matrix}OOC . CH_3\\OOC . CH_3\end{matrix}$$

melting at 157° were thus obtained.

Two experiments were then made as follows:

(*a*) ·72 grms. of sodium were dissolved in absolute alcohol and 5 grms. of malonic ester added. Dry ether was then added until turbidity began to appear. After standing a little while 5 grms. of iodoso-benzene acetate were added gradually and the mixture well shaken. Heat was developed and the mixture allowed to stand for some time.

(*b*) The same quantities were used and the reaction-mixture heated on the water-bath for several hours under the reflux.

In both (*a*) and (*b*), after filtering and distilling off the alcohol and ether, steam was conducted through the residues.

Phenyliodide distilled over, and long needle-like crystals separated from the solutions in great quantity. On re-crystallising these needles from ether they gave a melting point of 76° C. and reduced $AgNO_3$ to metallic silver and mercuric chloride to mercurous chloride.

The reaction therefore proceeds in a manner analogous to the action of iodine and of phenyliodide chloride on monosodium malonic ester. The yield however was very good, and much greater than in the analogous action of phenyliodide chloride. The precipitate filtered off was found on examination to be sodium acetate only, no sodium iodide being formed.

Action of phenyliodide chloride on sodium cyanacetic ester.

Two experiments were first made as follows:

(*a*) 1·673 grms. of sodium wire were dissolved in absolute alcohol and then 8·22 grms. of cyanacetic ester added gradually. To this solution absolute ether was added until the commencing point of turbidity was reached, and then 10 grms. of $C_6H_5ICl_2$ were added gradually and the mixture well shaken. Heat was developed and moderated by cooling the vessel. After standing for several hours, the precipitate formed was filtered off and found to contain only sodium chloride. The alcohol and ether were then distilled off, and the residue fractionally distilled under reduced pressure. After phenyliodide had distilled over, charring commenced and only a few drops of a light brown oil came over. This oil, however, did not contain any iodine.

(*b*) The same quantities were used and the reaction-mixture heated for several hours on the water-bath under a reflux. The same operations as above were then performed and the same results obtained, viz.: great charring and only a few drops of a light brown iodine free oil.

The same quantities were again used, and the reaction-mixture

heated for several hours on the water-bath under a reflux. After filtering and distilling off the alcohol and ether, steam was conducted through the mixture to get rid of the phenyliodide. The residue was then extracted with ether, and on distilling off the ether a light brown oil remained behind. On re-distillation in vacuo, partial decomposition took place and a light brown oil distilled over. This oil did not contain any iodine. The yield was small.

·095 grms. gave on combustion ·1855 CO_2 and ·0460 H_2O.

$$C = 53{\cdot}25\ ^{\circ}/_{\circ},$$
$$H = 5{\cdot}36\ ^{\circ}/_{\circ}.$$

$$\begin{matrix} CH\,.\,CN\,.\,COOC_2H_5 \\ | \\ CH\,.\,CN\,.\,COOC_2H_5 \end{matrix}$$ requires $C = 53{\cdot}57\ ^{\circ}/_{\circ}$ and $H = 5{\cdot}35\ ^{\circ}/_{\circ}$.

·088 grms. gave 9·4 c.c. of moist nitrogen at 758·6 mm. and 16·2° C.

$$N = 12{\cdot}43\ ^{\circ}/_{\circ}.$$

$$\begin{matrix} CH\,.\,CN\,.\,COOC_2H_5 \\ | \\ CH\,.\,CN\,.\,COOC_2H_5 \end{matrix}$$ requires $N = 12{\cdot}5\ ^{\circ}/_{\circ}$.

The oil is therefore dicyansuccinic ester.

Action of iodine on cyanacetic ester.

Since in the former experiments the action of phenyliodide chloride on mono- and di-sodium malonic esters respectively is analogous to that of iodine on the same esters, an experiment was performed to see if the same parallel existed in the case of cyanacetic ester.

11·23 grms. of iodine were dissolved in dry ether and allowed to flow gradually into a solution of sodium cyanacetic ester, which had been made by dissolving 2·03 grms. of sodium in absolute alcohol, adding 10 grms. of cyanacetic ester and then dry ether until turbidity appeared.

During the addition of the iodine the mixture was well shaken, and heated for seven hours on the water-bath under a reflux. A large excess of dry ether was then added to precipitate all the sodium iodide formed. Distilled water was then added and the mixture well shaken to dissolve out all the sodium iodide. The ether layer was separated and shaken up with sodium thiosulphate until all the free iodine was dissolved out of the ether layer.

The ether layer was then separated, filtered, and dried over $CaCl_2$. On distilling off the ether a light brown oil remained which was re-distilled in vacuo. A very good yield was obtained.

The oil contained no iodine.

·0975 grms. gave on combustion ·0485 H_2O and ·1915 CO_2.

H = 5·517,
C = 53·53.

$CH.CN.COOC_2H_5$
|
$CH.CN.COOC_2H_5$ requires H = 5·357 °/₀, C = 53·57 °/₀.

·2755 grms. gave 28·6 c.c. of moist N at 15·25° C. and 760·2 mm. pressure.

N = 12·15 °/₀.

$CH.CN.COOC_2H_5$
|
$CH.CN.COOC_2H_5$ requires 12·5 °/₀ N.

The action of iodine on sodium cyanacetic ester is thus perfectly analogous to that of phenyliodide chloride on the same ester.

Action of iodoso-benzene acetate on sodium cyanacetic ester.

The action of iodoso-benzene acetate was tried and gave the same results as the two preceding reactions.

The experiment was performed in precisely the same way, the quantities used being as follows:—

10 grms. of cyanacetic ester,
2·03 „ „ sodium wire,
14·25 „ „ iodoso-benzene acetate.

A light brown oil was obtained, and after re-distillation in vacuo a combustion resulted as follows:

·125 grms. gave ·244 CO_2 and ·063 H_2O. C = 53·2 °/₀,
H = 5·59 °/₀.

$CH.CN.COOC_2H_5$ H = 5·357 °/₀.
|
$CH.CN.COOC_2H_5$ requires C = 53·57 °/₀.

Thus all three preceding reactions give the same final product.

The action of diphenyliodonium iodide on monosodium malonic ester, both at ordinary temperatures and also at the temperature of the boiling water-bath for several days, was tried, but nothing appeared to take place. Probably a much higher temperature may be required to effect a reaction, and the author hopes to try experiments using sealed tubes at some future date. Under the conditions employed in the foregoing experiments the author concludes phenyliodide chloride and iodoso-benzene acetate have analogous properties to iodine itself, when acting on the sodium compounds of malonic and cyanacetic esters.

Finally, the author desires to express his gratitude to Mr H. O. Jones for the extremely kind interest he has taken in this work, and for much help and advice during the progress of the experiments.

The Radioactivity of Potassium, with special reference to solutions of its salts. By NORMAN CAMPBELL, M.A., Trinity College.

[*Read* 18 May 1908.]

I. *Attempt to separate the activity.*

§ 1. In former communications to the Society* the remarkable activity displayed by the salts of potassium has been described. It appears to be due to the emission of β rays, some of which approach in penetrating power the β rays of uranium, and to be closely connected with the presence of the element potassium. All the salts examined showed the activity in an amount approximately proportional to the potassium content, but no other bodies examined seemed to emit similar rays.

There remains for decision the important question whether the association with potassium of the element (for all analogy leads to the belief that it must be an element), which is responsible for the activity, is fortuitous or essential. The association may be due merely to a close similarity in chemical properties between the potassium and the active element, or it may be due to the fact that the active element is potassium itself or that it is descended from that element as radium is descended from uranium.

Whichever of these alternatives is true it becomes important to try to separate from a potassium salt some part of its activity. The experiments about to be described were undertaken with that object: complete failure to effect any separation has been their result, but incidentally phenomena have been observed which are of some interest.

§ 2. The measurement of the activity of the preparations was made in all cases in the vessel described on p. 212 of the first paper quoted above. The preparations were placed in trays of an area of 500 cm.^{2} and a depth of 0·5 cm., which they filled completely. The current through the vessel, when the trays were placed beneath the large window (about 1450 cm.^{2}) of thin aluminium leaf, was compared by means of the compensation method previously used with the current when the trays were replaced by similar empty trays. The probable error of a single observation was about one of the arbitrary units used in the

* *Proc. Camb. Phil. Soc.* xiv. 1. 15—21 and xiv. 2. 211—216.

tables: the figures given are usually the mean of four successive observations.

Whenever material from a new source was introduced, care was taken that it contained no radium or other active element, giving rays of a nature different from those of the potassium salts. For this purpose another set of measurements was made in which the material was covered with a layer of tin-foil thick enough to absorb all α rays. In no case was the proportion absorbed by the tin-foil different from that absorbed when a pure potassium salt, tested for radium by the emanation method, was used. It may be concluded, therefore, that all the activity measured was due to the active element of the potassium salts.

The salts obtained commercially as "pure" were assumed to contain the theoretical amount of potassium. In most other cases the salts were analysed. These analyses were carried out in the agricultural laboratory by the cobalticyanide method, and I am deeply indebted to Prof. T. B. Wood for his kindness in having these estimations made.

§ 3. Table I gives a summary of the chief observations.

TABLE I.

Material	$\%$ K_2O	Activity	Activity of K_2O (calc.)
K_2SO_4 (1)	54	87	161
(2)	54	87	161
(3)	54	86·5	160
(4)	54 (?)	85	157·5
(5)	9·1	14·4	158
(6)	51·0	82	161
(7)	46·0	75	163
(8)	54 ?	87·5	162
KCl (1)	63·1	102	162
(2)	63·1	102	162
(3)	63·1 ?	100	159·5
KNO_3 (1)	46·5	72·5	156
(2)	46·5	70	151
KCN (impure)	57	103	181
KI	28·2	39·5	141
$K.C_2H_3O_2$	48·5	66	136
K_2CO_3	68	103	152
$KClO_3$	38·4	63	167
K_2SO_3 (impure)	56·3	87·5	155
Sylvine (KCl)	62·5	102	163
'Muriate of Potash'	51	82	161
Kainite	16	22·5	141

In the first paper by Mr Wood and myself on the activity of potassium experiments were described on samples of salts derived from different sources. These experiments have been repeated with greater accuracy. Three samples of the sulphate (Nos. 1, 2, 3 of Table I) were procured from different chemical manufacturers: their activity was identical within the limit of error. A fourth sample (No. 4) was prepared from the ashes of burnt wood: it was known to be slightly impure, but its activity does not show any marked difference from that of the commercial samples derived from the Stassfurt deposits. Similar agreement was found between two samples of the chloride (1 and 2) and between two samples of the nitrate.

It is indeed inherently improbable that any difference in commercial samples should be found, whatever the nature of the active principle: for nearly all commercial samples come from the same source. But the agreement of the sample derived from wood ashes seems to show that the association of the active principle with potassium is very close and that separation, even if it is possible, is likely to be very difficult.

§ 4. When different salts of potassium were compared, it became apparent that the activity of a thick layer is not simply proportional to the percentage of potassium contained in the material of which it is composed. The variations from proportionality are shown in Table I, where the last column gives the activity of a thick layer of K_2O calculated from the content and the activity of the material named in the first column. It must be remembered that the activity of a thick layer of an active substance is proportional not only to the content of the active element, but also to the ratio of the density to the absorption coefficient of the material for the rays which it emits. If $A\,dm$ is the intensity of the total radiation emitted by a small particle of the substance of mass dm, λ the absorption coefficient of the substance for its own rays and ρ the density. it is easy to show that the intensity (I) of the radiation (the absorption of which is supposed to follow the exponential law) emerging from a layer of thickness x is given by

$$I = A\rho/\lambda\,(1 - e^{-\lambda x}) \quad \text{.....(1),}$$

and the intensity I_0 of the radiation from an infinitely thick layer is

$$I_0 = A\,.\,\rho/\lambda \quad \text{.....(2).}$$

If the proportion of the active substance by weight present is α, we must substitute $\alpha\rho$ for ρ. For all substances the quantity A should be constant, where

$$A = \frac{I_0}{\alpha}\,.\,\lambda/\rho \quad \text{.....(3).}$$

Since the value of λ in these experiments is not less than 10, the activity of a layer 0·5 cm. thick will not differ from that of an infinite layer by more than $1\frac{1}{2}$ %, and the apparent activity of materials containing the same proportion of potassium should be inversely proportional to the value of λ/ρ.

To test the view that the variation in the calculated values of the activity of K_2O is due to variations in this quantity and not in the activity of the potassium, a sample of the sulphate was prepared from the nitrate which gives too low a value for K_2O. The activity of this sample is given in Table I, No. 8, and agrees well with that of the other samples. Potassium sulphate Nos. 5 and 6 were prepared from the specimen of kainite shown in Table I, and No. 7 from the "muriate of potash." Potassium chloride No. 3 was prepared from potassium sulphate No. 2 by precipitation with barium chloride. It appears then that, though the activity is not always proportional to the content of potassium, it is always the same when the apparently abnormal compound is turned into sulphate or chloride. The explanation by means of the absorption coefficient seems more reasonable than the only alternative, that the activity actually varies with the state of chemical combination, for no such variation has been observed in any other case of radioactivity. It is, moreover, supported by the observations on solutions described in the later part of this paper.

It may be noted that, while the value of K_2O deduced from the iodide is lower than that deduced from the sulphate in these experiments, it is too high in those of a former paper. This circumstance accords well with the hypothesis just suggested, for in the former experiments the layers were only 0·15 cm. thick. If the value of λ is greater for the iodide than for the sulphate, a layer of this thickness would be more nearly "infinitely thick" for the former than for the latter salt. In thin layers the iodide may appear more active, in thick layers less active than the sulphate.

§ 5. Since no evidence could be found of a separation from potassium of any part of its activity in salts obtained by the methods described, an endeavour was made to effect a separation by the means employed in the study of the decomposition products of the elements recognised as radioactive.

(1) 400 grammes of potassium sulphate were heated to a dull redness for eight hours and to the highest temperature attainable in a blow-pipe flame for 15 minutes. No change was produced in the activity measured after cooling.

(2) In the former paper quoted above an account was given of an attempt to separate the activity by re-crystallisation. This attempt has been repeated with yet greater care. 1000 grammes of the sulphate were dissolved in such a quantity of water that

the solution was saturated at its boiling point. The residue poured off from the crystals after cooling was taken as the first fraction. The process of solution and crystallisation was repeated in the same manner 21 times, and the crystals of the last operation were taken as the second fraction. The most careful experiments failed to show any difference between the first and last fractions, though a difference of 1 % could have been detected with certainty.

(3) Aluminium hydroxide, barium sulphate, silver chloride, and copper sulphide were precipitated from aluminium sulphate, barium chloride, silver nitrate and copper sulphate respectively mixed with separate portions of a strong solution of potassium sulphate. No activity similar to that of potassium could be detected in the precipitates. The potassium sulphate remaining was not examined, for it was thought that the impurities introduced in the processes of precipitation would render any result that might be obtained devoid of value.

(4) A current of three ampères was passed for four hours between electrodes of platinum wire immersed in about 5 litres of a strong solution of potassium chloride. Immediately after the operation the electrodes were taken out, rinsed and examined for activity. No activity whatever could be observed.

These four methods include most of those that have been used for the separation of radioactive products. They all yielded negative results. For the present, therefore, I have abandoned as hopeless the attempt to effect a separation, though I do not regard it as certain that others with better opportunities and greater chemical skill may not obtain a more favourable result. Even if potassium is intrinsically radioactive, it is contrary to all precedent that only one member of a radioactive series should show activity.

II. *The activity and absorption of solutions.*

§ 6. While endeavouring to find some preparation of a potassium compound which would show an activity differing markedly from the normal, it occurred to me to try the activity of such a compound in the state of solution. It was discovered at once that the activity of a solution was considerably less than that which would be predicted from the amount of potassium which it contains: the variation is shown in Table II, which gives a few of the many observations made upon solutions.

TABLE II.

Salt in solution	% K_2O	Activity	Activity K_2O
K_2CO_3	9·8	14·0	143
,,	10·8	16·5	153
,,	19·0	26·0	137
,,	25·7	31·0	121
,,	29·5	38	129
,,	33·0	46	140
KOH	26	31·0	120
KNO_3	9·8	14·5	148
KI	14·7	20·5	139
K . $C_2H_3O_2$	24·5	30·5	124
,, (in alcohol)	8·64	9·9	115

Not only are the activities of solutions smaller than those of solids, but they appear to be much more variable. Successive measurements made on a solid always agree to two or three units: successive measurements on a solution often differ by twenty units and it is only by taking some ten or fifteen observations that a mean can be obtained which can be reproduced to the same degree of accuracy as a single observation on a solid. Many variations in the apparatus have been tried in order to get rid of this variation but none have been successful. No explanation can be offered at present, but the phenomenon is probably connected with the abnormality of the activity.

§ 7. When rearrangement of the apparatus had failed to get rid of the peculiarity of solutions, a few rough experiments were tried on solutions of uranium. Table III shows the results. It

TABLE III.

Substance	% UO_3	Activity	Activity UO_3
UO_3	100	·790	·79
Solution (1)	35·6	·278	·78
,, (2)	23·4	·196	·84
,, (3)	22·5	·182	·82
,, (4)	16·4	·131	·80
,, (5)	13·0	·117	·90
,, (6)	10·7	·092	·86

will be observed that none of the solutions show an activity less than that which would be expected from their content of uranium: the deviation is in the opposite direction to that of the potassium salts and is in the direction which might be expected from what is known of the value of λ/ρ for β rays. The experiments of

Crowther and others on the rays from uranium show that this quantity generally increases with an increase in the density of the absorbing material: the solutions, both of uranium and potassium, were less dense than the corresponding solids.

If the density of preparations of uranium is constant, it appears that the activity is dependent only on the content of uranium. A weak solution of uranium was made containing ·00067 gramme U per c.c. 210 c.c. of this solution placed in the tray gave an activity of 82. The same volume of the solution was then evaporated to dryness with 210 grammes of ammonium chloride, which is approximately of the same density as water. The activity of the solid resulting was 82·5. Incidentally it was found that uranium is 390 times more active than potassium as measured by the ionisation produced by its β rays in the apparatus used. But the value of this ratio deduced would depend on the nature of the ionisation vessel used.

§ 8. Experiments were then made on the absorption of the β rays of uranium in solutions of potassium carbonate. A full account of these experiments and those which have arisen out of them will be given in a later paper. Here it will suffice to say that it appeared at once that the value of λ/ρ in solutions cannot be predicted simply from that of the solute and solvent: solutions show remarkable abnormalities which made it appear possible that the small apparent activity of the potassium solutions might contrary to expectation, be explained by examining their absorption of the rays that they admit. An attempt was made accordingly to measure directly the coefficient of this absorption.

§ 9. For this purpose the activity of layers of varying thickness was measured and the results compared with the theoretical equation

$$I = I_0(1 - e^{-\lambda x}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4).$$

In the case of the solution the thickness x was estimated from the volume of the solution and the area of the tray σ (new trays were used): in the case of the solid the mass of the salt (m) spread evenly over the tray was measured and the equation used in the equivalent form

$$I = I_0(1 - e^{-\frac{\lambda}{\rho}\cdot\frac{m}{\sigma}}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4a)$$

leading to a direct determination of λ/ρ.

The experiments lead to an evaluation of I_0 and λ/ρ. α (equation (3)) is also known and hence the values of $\frac{I_0}{\alpha}\cdot\lambda/\rho$, a quantity which ought to be constant, can be found.

TABLE IV.

Solution in water, containing 37·5 °/₀ K_2CO_3.
Density = 1·3887 = ρ.
Area of tray = 1008 cm.^{2} = σ.

Volume of solution in tray = σx	Activity = I
55 c.c.	39
57 „	38·5
65 „	38·5
66 „	37·5
70 „	51
71 „	44·3
79 „	49·5
82 „	51·5
95 „	60·5
121 „	64·0
135 „	64·3
150 „	67·5
165 „	62·0
170 „	72·3
193 „	69·0
202 „	72·8
297 „	76·5
343 „	77·0

TABLE V.

Pure K_2SO_4 (Kahlbaum).
Area of tray = 1011 cm.^{2} = σ.

Mass of salt in tray = m	Activity = I
9·9	15·8
20·1	27·1
30·5	44·0
39·7	56·8
49·6	67·5
59·4	76·8
69·3	87·1
84·8	98·1
97·0	108·7
120·0	131·2
144·0	140·0
174·0	157·5
200·0	166·1
501·0	202·0

Tables IV and V give the measurements made. From these figures rough values of I_0 and λ can be found by graphical methods. To correct these rough estimates, the following procedure was adopted.

Let I_0' and λ' be the approximate values; $I_0' + dI_0$ and $\lambda' + d\lambda$ the most probable values, so that $I_0 = I_0' + dI_0$ and $\lambda = \lambda' + d\lambda$.

Then, if I is the observed activity of a layer of thickness x,

$$I = I_0(1 - e^{-\lambda x}) = (I_0' + dI_0)(1 - e^{-(\lambda' + d\lambda)x}).$$

Expanding by Taylor's theorem and neglecting terms in $(d\lambda)^2$ and $dI_0 d\lambda$, we have

$$dI_0(1 - e^{-\lambda' x}) + xI_0' e^{-\lambda' x} . d\lambda = I - I' \text{ .....(5)},$$

where $I' = I_0'(1 - e^{-\lambda' x})$, the value of I calculated from the approximate values of I_0' and λ'.

Substituting in (5) the observed values of I and x, and the approximate values I_0' and λ', we obtain a series of linear equations in dI_0 and $d\lambda$. These equations are solved by the usual least square method.

The following results were obtained.

For the solution of Potassium Carbonate

$$\lambda = 12{\cdot}54 \pm 0{\cdot}57, \qquad \therefore \quad \lambda/\rho = 9{\cdot}016 \pm 0{\cdot}41,$$
$$I_0 = 78{\cdot}34 \pm 1{\cdot}45 \quad \text{and} \quad I_0 . \lambda/\rho = 706 \pm 18.$$

For the solid Potassium Sulphate

$$\lambda/\rho = 8{\cdot}23 \pm 0{\cdot}1,$$
$$I_0 = 204{\cdot}2 \pm 2{\cdot}9 \quad \text{and} \quad I_0 . \lambda/\rho = 1680 \pm 37.$$

The solution contains $37{\cdot}5 \times \frac{94}{138}$ °/₀ of K_2O; the solid contains $\frac{94}{174}$ °/₀ K_2O. Hence the calculated values of $I_0/\alpha . \lambda/\rho$ are

$$2766 \pm 70 \text{ from the solution,}$$
$$3107 \pm 68 \text{ from the solid.}$$

§ 10. There is not perfect agreement between these numbers, but the interesting result appears that the value of λ/ρ is actually greater for the solution than for the solid and, therefore, that the discrepancy introduced by the difference in these values is of the order and in the direction necessary to explain the apparent activity of thick layers. Indeed it is not to be expected that the value of λ obtained by the measurements which have just been described should be such as to give a constant value of $I_0/\alpha . \lambda/\rho$. For it has been shown previously that the rays from potassium are not homogeneous, but differ considerably in penetrating powers. The absorption does not follow an exponential law strictly and the value of λ obtained is only a mean value of the many different values. This conclusion is confirmed by the present measurements, for the probable error of I_0 deduced is much greater, especially in the case of the solid, than that which would have been expected from the known accuracy of the observations. The calculated probable error is too great because the relation between the intensity and the thickness is not really indicated accurately by equation (4) in which λ is taken as the same for all rays.

Now if the active layer is emitting rays of different penetration, the softer rays will produce more than their fair share of the ionisation: for the harder rays pass through the ionisation vessel without being completely absorbed in the air contained in it. On the other hand, it is easy to see that in the measurements of the absorption coefficient the harder rays produce a greater effect upon the result than the softer rays, for the harder rays continue to cause a variation of the activity with the thickness of the layer after the layer has become so thick that it is practically infinite for the softer rays. All experiments have indicated that the variations of λ/ρ are greater for soft rays than for hard. Hence in measuring this quantity for rays which are, on the average, harder than those which produce the ionisation, the correction for the difference in the value of λ/ρ has been underestimated.

For this reason it has seemed of no use to continue the extremely tedious work of measuring the absorption coefficient of the various potassium preparations. It has been shown in one instance—and that instance the most abnormal—that the variations of the absorption are such as to account, at least in part, for the deviation from proportionality to the content of potassium of the apparent activity.

It may be noted that the heterogeneity of the rays for potassium suggests that a separation of the activity should be possible. For recent work tends to show that the apparent heterogeneity of the radium rays is due to the presence of several different elements emitting rays of different quality.

I conclude, therefore, that while it has not been proved indisputably that the activity of the potassium is the same in whatever state of chemical or physical combination it occurs, there is no evidence that the activity is not the same. It appears more probable that the differences in the apparent activity of different preparations of potassium are to be attributed to a difference in the value of λ/ρ for such preparations than to a difference in the activity of the potassium.

§ 11. The following conclusions may be drawn from the work described above:

(1) All attempts to observe or to produce any difference in the activity of different samples of the same potassium compound in the same physical state have failed completely. No evidence has been obtained of any such separation of the activity as is to be expected whatever view may be taken of the source of the activity.

(2) The activity of a thick layer of a potassium compound is not accurately proportional to the amount of potassium which it contains. It is probable that the variation from strict proportionality is to be attributed to a difference in different compounds

of the values of the ratio of the density of the substance to the absorption coefficient of the rays emitted by it. In the case of solutions, at least, the variations in the value of this ratio are surprisingly large and irregular. The ratio is not necessarily greater for the solution of greater density or greater concentration.

Note.

As this paper is on the point of publication, too late for any further observations to be made, a letter has appeared in *Nature* in which Prof. McLennan describes experiments by himself and Mr Kennedy leading to conclusions exactly contradictory to those which have been urged above. He states that the activity of potassium compounds is not even approximately constant, but extremely capricious: large variations may be noted in different samples of the same salt.

Enough details are not given to admit of a thorough comparison between the methods which have led to such different results, but it may be noted that Prof. McLennan and Mr Kennedy place their active material inside the ionisation chamber, while my material was separated from the chamber by thin aluminium leaf or, as in the former experiments, by wire gauze, the potential of which differed by equal amounts from the electrode and that of the active material. If, beside the penetrating rays from potassium, there are also very soft rays emitted, or even ions with no velocity of their own, the discrepancy of our results might be explained. The observations which have been made on absorption indicate that the apparent activity of an active substance giving very soft rays might exhibit great complexity. There are also considerable dangers in placing substances which are hygroscopic or produce vapours, such as the cyanide, directly in contact with the air of which the ionisation is measured.

(Added June 16.)

In view of Prof. McLennan's results, the activity of samples of potassium sulphate prepared from the cyanide and acetate mentioned in Table I has been examined. No difference can be detected between these samples and those given in the table.

I have attempted to repeat Prof. McLennan's work by placing trays containing the potassium preparations inside the ionisation vessel. However it was found that the change in the 'natural ionisation' of the vessel caused by the admission of fresh air, when the vessel was opened to insert the tray, was so large and irregular that it was impossible to obtain consistent results for the activity of a single sample.

The absorption spectra of some compounds of pyridine. (Third paper.) By J. E. Purvis, M.A., St John's College.

[*Received* 18 May 1908.]

The absorption spectra of various compounds of pyridine and collidine have been already studied by the author and Foster (*Proc. Camb. Phil. Soc.* vol. XIV. pt. IV. p. 381 and pt. V. p. 435). It was proved that the persistence of the absorption band of various chlorine derivatives increased according to the number of chlorine atoms introduced into the nucleus, and that on loading the ring by increasing the number of chlorine atoms, the band was shifted towards the red end. The observations confirmed the previous observations of other compounds of pyridine by Baker and Baly (*Journ. Chem. Soc.* vols. 91 and 92, pp. 1122—1132).

It was further shown that when the chlorine atoms were introduced into the side chains, as in 9-chlorocollidine, the increased number of atoms did not increase the persistence of the band, but decreased it a little less than that of the collidine band, although there was a considerable shift of the band towards the red end.

Also, with regard to a compound called 7-chlorolutidine which had been obtained from 9-chlorocollidine, the increased persistence of the band indicated the great probability that six of the chlorine atoms had replaced the six hydrogen atoms of the side chains, whilst the remaining atom had entered the nucleus.

In Baker and Baly's investigations (*loc. cit.*) it is stated that the shifts of the bands of the isomeric compounds of picoline were different and that, expressed in oscillation frequencies, they were:

α-picoline, 3875,
β-picoline, 3800.

Baly and Collie (*Journ. Chem. Soc.* 1905, p. 1332) have also pointed out that the introduction of a single group modifies the absorption spectrum of benzene, different types of absorption being produced according to the nature of the group introduced.

And Baly and Ewbank (*Journ. Chem. Soc.* 1905, p. 1355), in the case of disubstituted derivatives of benzene, have proved that

the ortho-, meta-, and para-compounds show considerable differences in their absorption curves.

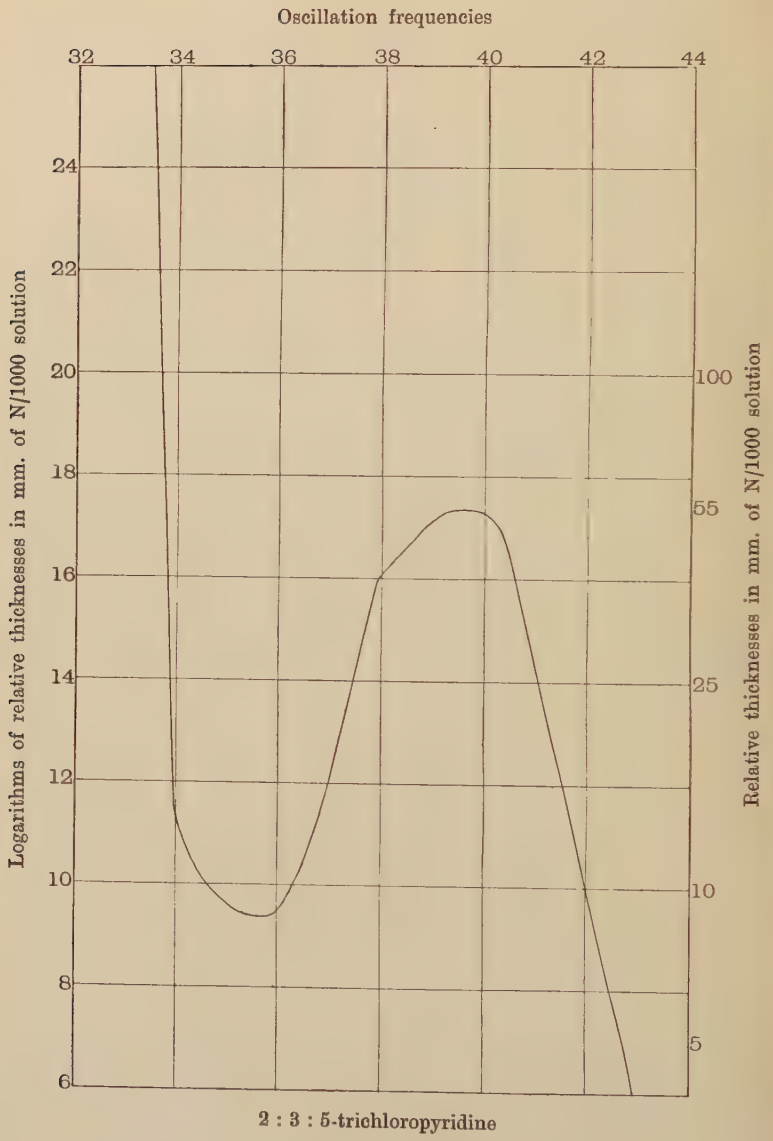
These observations suggest that the position of the absorption band and its persistency do not entirely depend upon the number of atoms introduced into the nucleus. The type and position of the introduced atom or group of atoms appear to exert considerable influence. In other words, the spatial relationship of the nucleus and its side chains must be taken into consideration; and, in this direction, the aim of this paper is to describe some investigations with several compounds of pyridine.

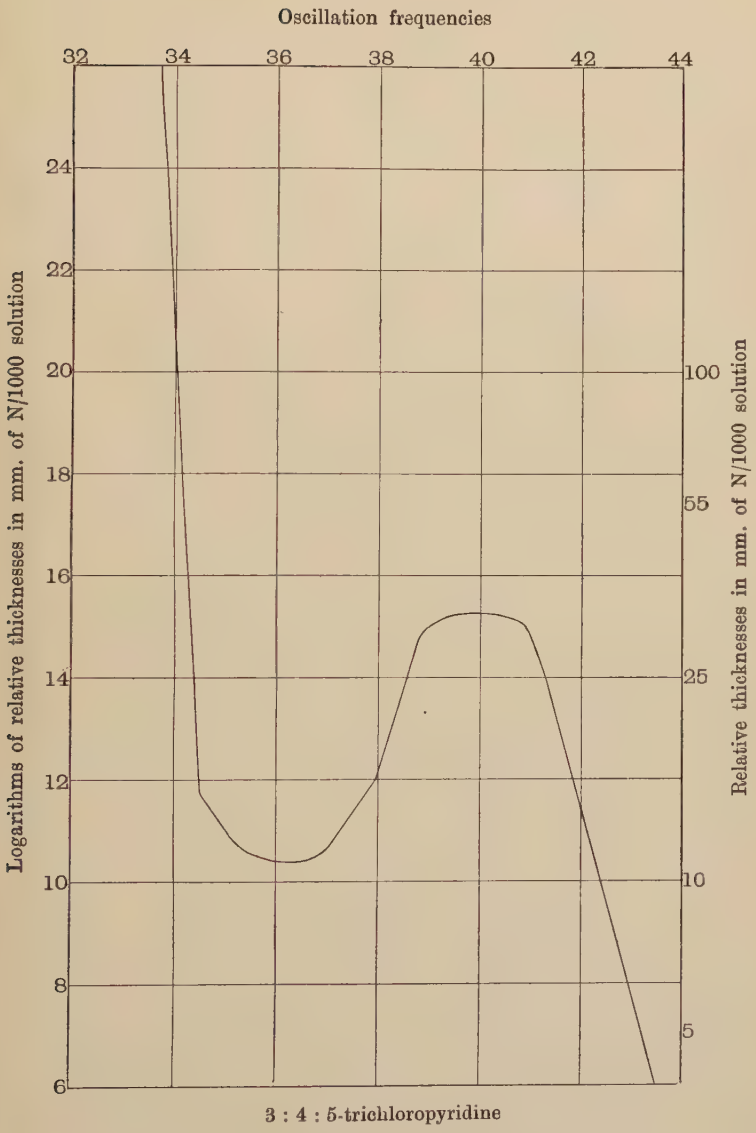
The apparatus used in the experiments has been described in the previous papers and the method of plotting the curves is exactly the same as before.

Trichloropyridines. The two compounds investigated were 2:3:5-trichloro-, and 3:4:5-trichloropyridines. The latter has been previously described by Baker and Baly (*loc. cit.*): but I have examined the absorption curve again so as to make it more comparable with the 2:3:5-compound under the same conditions. The curve obtained from the 3:4:5-trichloropyridine is essentially like that obtained by Baker and Baly.

With regard to the 2:3:5-trichloropyridine, it is noticeable that the general form of the absorption curve is very like that of the 3:4:5-trichloropyridine, but there are marked differences in the position and persistency. The absorption band of the 2:3:5-compound is shifted towards the red end of the spectrum a little further than that of the 3:4:5-compound, whilst the persistency is considerably increased. The positions of the bands, expressed in oscillation frequencies, are:

2:3:5-trichloropyridine, 3580,
3:4:5-trichloropyridine, 3650.


Oscillation frequencies
32
34
36
38
40
42
44
24
22
20
18
16
14
12
10
8
6
Logarithms of relative thicknesses in mm. of N/1000 solution
100
55
25
10
5
Relative thicknesses in mm. of N/1000 solution
2 : 3 : 5-trichloropyridine


Oscillation frequencies
32
34
36
38
40
42
44
24
22
20
18
16
14
12
10
8
6
Logarithms of relative thicknesses in mm. of N/1000 solution
100
55
25
10
5
Relative thicknesses in mm. of N/1000 solution
3 : 4 : 5-trichloropyridine

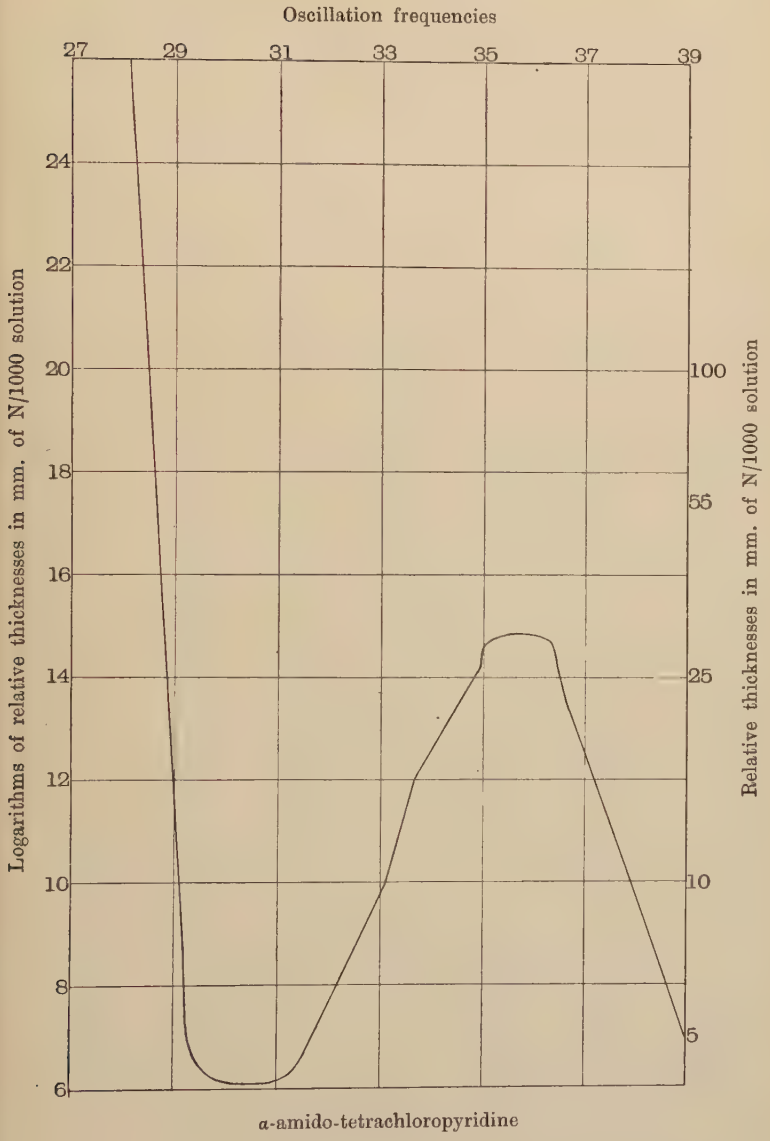
The shift and the persistency of the band may perhaps be explained in the following way. If the number of internal motions in a given time is greater in the 2 : 3 : 5-compound than in the 3 : 4 : 5-compound, there may be a greater absorption of light and therefore an increase in the intensity of the band. The increased intensity would be revealed not only in the increased persistency, but also in the apparent shift of the band towards the red end. Or, the position of maximum intensity of the band may be altered by an unsymmetrical broadening of the band, for it is well known that absorption bands vary very considerably. Some are sharp on one edge, and diffuse on the other; whilst the edges of others are unequally diffuse, and therefore the position of maximum intensity is not a central one.

Amido-chloropyridines. The two compounds investigated were *a*-amido-tetrachloropyridine and γ-amido-tetrachloropyridine. In order to compare the absorption curves obtained from these compounds with that of 5-chloropyridine, I have re-examined the latter, and it appears to give a curve very similar to that found by Baker and Baly (*loc. cit.*). And although there is a general similarity in the form of the curves obtained from the three compounds, there are considerable differences in the positions and persistencies.

If the curves of the *a*- and the γ-compounds are compared, it will be seen that the former indicates a considerably greater shift of the band towards the red end, and also a considerably greater persistency. The band of the γ-compound is almost wiped out. And, on comparing these two curves with that of the 5-chloropyridine, there is a greater shift of the *a*-compound and a less shift of the γ-compound. But the persistency of the band of the 5-chloropyridine is greater than that of the *a*-compound, and very considerably greater than that of the γ-compound.

The positions of the bands, expressed in oscillation frequencies, are:

a-amido-tetrachloropyridine,	3050,
γ-amido-tetrachloropyridine,	3550,
5-chloropyridine,	3400.


Oscillation frequencies
27
29
31
33
35
37
39
24
22
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16
14
12
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8
6
Logarithms of relative thicknesses in mm. of N/1000 solution
100
55
25
10
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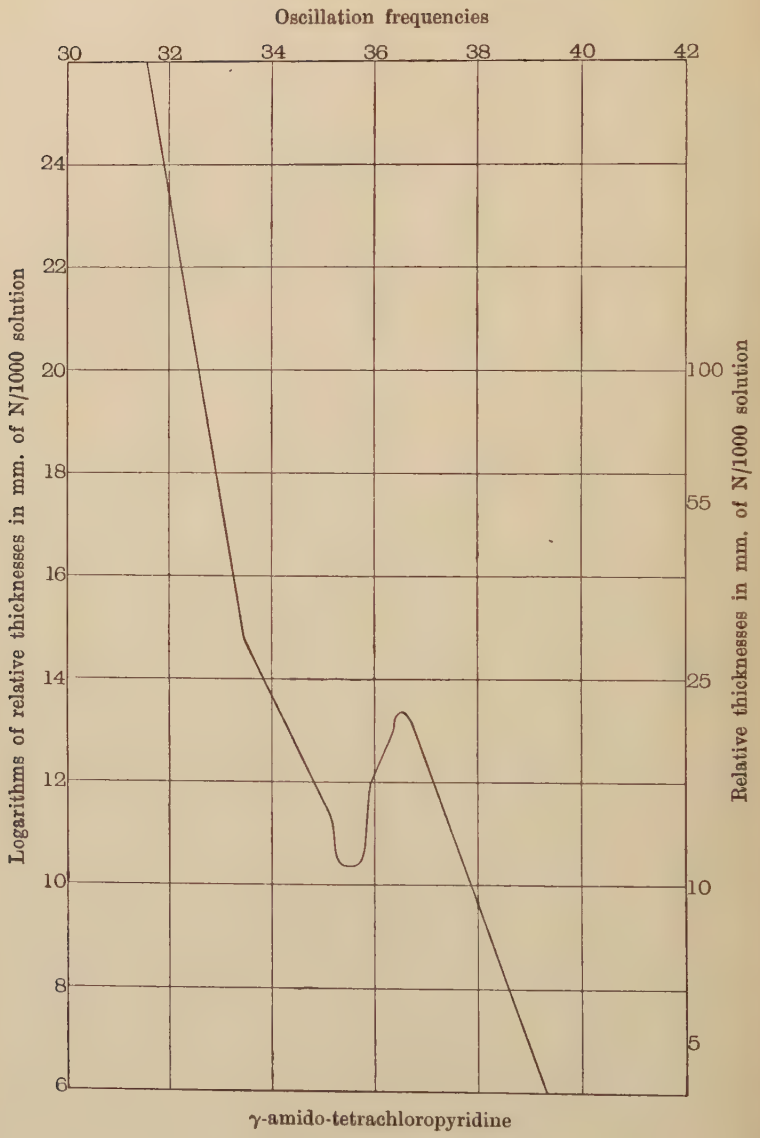
Relative thicknesses in mm. of N/1000 solution
α-amido-tetrachloropyridine


Oscillation frequencies
30
32
34
36
38
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42
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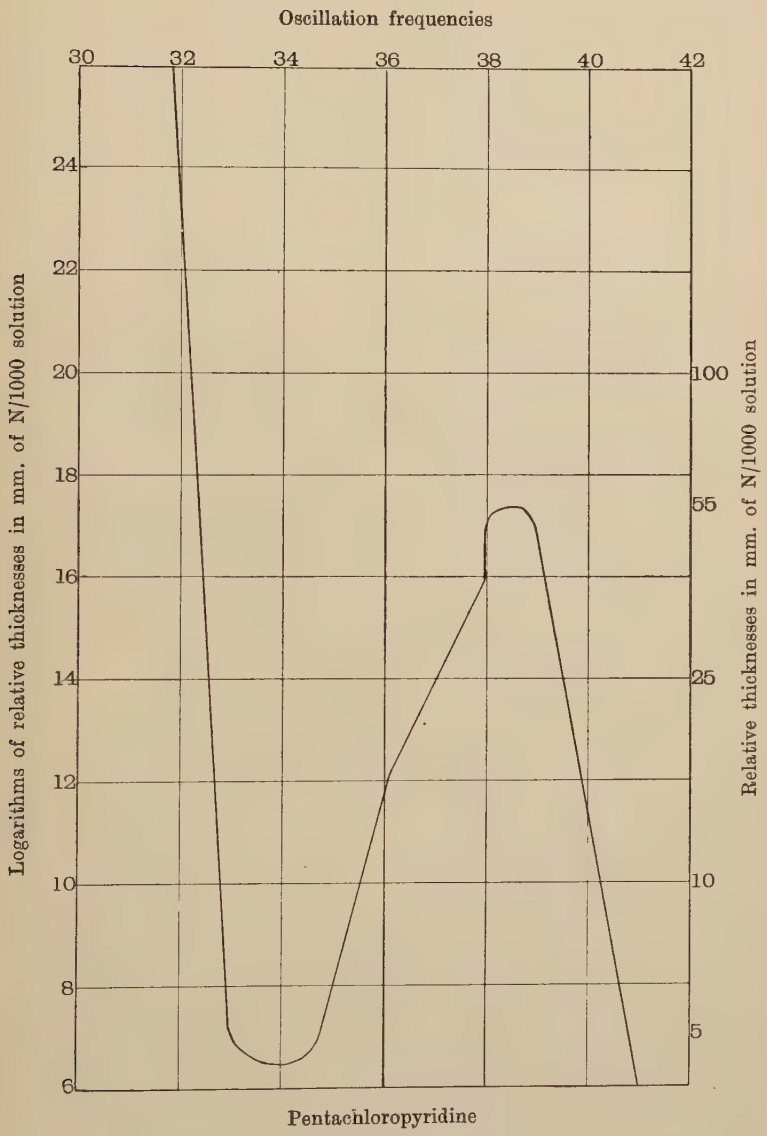
6
Logarithms of relative thicknesses in mm. of N/1000 solution
100
55
25
10
5
Relative thicknesses in mm. of N/1000 solution
γ-amido-tetrachloropyridine


Oscillation frequencies
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6
Logarithms of relative thicknesses in mm. of N/1000 solution
100
55
25
10
5
Relative thicknesses in mm. of N/1000 solution
Pentachloropyridine

These results, therefore, show that the shift of the band towards the red end and also its persistency are not necessarily dependent upon the number and mass of the atoms or radical groups introduced into the nucleus. Their type and spatial relationships or orientation must be taken into consideration.

Baly and Desch (*Astrophysical Journal*, vol. XXIII. pp 110—127) in a study of the absorption spectra of some aliphatic compounds exhibiting tautomerism and showing absorption bands, state that the oscillation frequency of an absorption band varies slightly with the total mass of the molecule, but that it is not directly dependent upon the mass of the labile atom. Again, they suggest that the persistency of the absorption band is a measure of the number of molecules in the changing state at a given time.

The oscillation frequencies of the α- and β-picolines investigated by Baker and Baly (*loc. cit.*) are not identical; neither are those of the two 3-chloropyridines nor the two amido-compounds of this investigation; and it may be possible to extend the theory to closed ring compounds.

Applied to the compounds of this investigation, it means that the number of changes in the 2:3:5-trichloropyridine is greater than in the 3:4:5-compound. Whilst the number of changes in the γ-amido-compound is considerably less than in the α-amido-compound; or, as stated before, the spatial positions of the atoms or groups of atoms in a ring compound influence the number of vibrations in a given time.

And, first, with regard to the two trichloropyridines. It may be that the relative positions of the three chlorine atoms in the 2:3:5-compound are such that their motions with regard to the other atoms and themselves are less hindered than in the 3:4:5-compound, with the consequent production of a greater number of changes in a given time. A greater absorption of light vibrations is thereby produced, and the result is observed in a greater persistency of the band. And as regards the two amido-compounds, the relative positions of the radical groups compared with the other atoms, are such that the number of changes in the molecules in a given time in the α-compound is less than in the 5-chloro-compound, thereby producing less absorption of light, and therefore there is a less persistency of the band. And the number of changes in the vibrations of the γ-compound is so much less, that the absorption of light is very considerably diminished.

Now as regards the α- and γ-amido-tetrachloropyridines, the relative positions of the two NH_2 groups are of considerable importance in influencing the absorption of light. In the γ-compound, the orientation of the NH_2 radical and the other atoms of

the molecule, particularly the relative position of the nitrogen atom of the nucleus and the NH_2 radical, may hinder the vibrations so that the number of vibrations is considerably less than in the *a*-compound, with a consequent less absorption of light, and, therefore, a very great decrease in the persistency of the band. On the other hand, it is necessary to point out that the persistency of the band and its shift may also be connected and explained, in a similar manner as in the case of the trichloropyridines (p. 572).

General Conclusions.

But whatever be the physical explanation of the differences in the shifts and persistencies of the absorption bands of these allotropic compounds obtained from pyridine, the absorption curves indicate that:

(1) The *relative positions* of the absorption bands are influenced by the type and the spatial positions of the atoms or groups of atoms introduced into the nucleus, and

(2) The *persistencies* of the bands are also influenced by the type and the spatial positions of the atoms or groups of atoms introduced into the nucleus.

I wish to thank Dr Sell for his great kindness in giving me specimens of the pure substances used in this investigation.

A Preliminary Note on an Effect observed when Palladium Foil is heated in Air at a low Pressure. By Rev. H. V. Gill, Downing College. (Communicated by Professor Thomson, F.R.S.)

[*Read* 18 May 1908.]

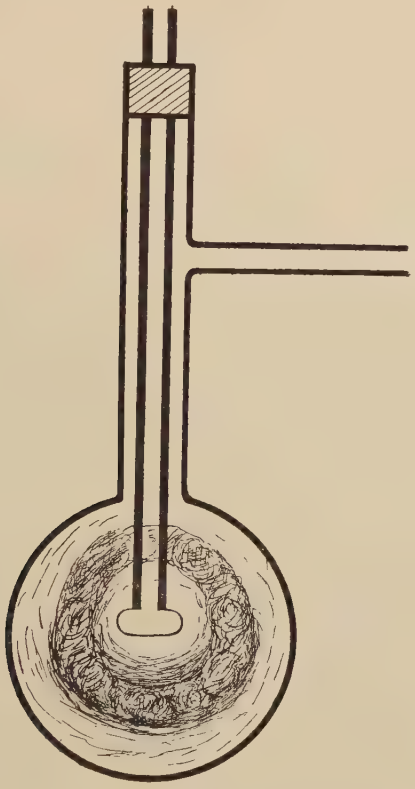
When making some preliminary experiments in connection with an investigation, suggested by Professor J. J. Thomson, concerning the discharge of electricity from palladium electrodes a phenomenon was observed which does not seem to have been hitherto noticed. The object of this note is only to put on record the fact as observed, reserving a fuller account of experiments which are being made at the Cavendish Laboratory to determine the nature and causes of the effect.

A vacuum tube had been fitted up containing a piece of palladium foil about an inch long and $\frac{1}{8}$ inch wide, mounted at the extremities of two leads so that its temperature could be raised by means of an electric current. This tube was sealed on to a mercury air-pump, pressure-gauge, and drying bulb, and could be separated from them by means of a mercury seal.

The foil was gradually heated in air at a pressure of about 0·15 mm. When the palladium was at a white heat there became visible around it a glow, not unlike the "negative glow" in a vacuum tube discharge. There was, however, no electric field except that due to the current from the two storage cells employed to heat the foil.

The glow is of a rich purple-blue colour, and is quite visible in a darkened room in spite of the glare from the white-hot palladium. On the first occasion this glow was observed in a tube about one inch in diameter, and appeared to extend to the walls of the tube. Afterwards bulbs about four inches in diameter were made use of (see fig.). There appeared to be a "dark space" between the hot metal and the glow, but it is not easy to decide if there really is a space. What appears to be an interval between them may be merely the effect of contrast due to the glare. However, the majority of those who have seen this phenomenon are inclined to think there really is a "dark space." In bulbs of the size just mentioned the glow does not extend to the walls, but formed

a ring about three-quarters of an inch in thickness all round the hot palladium foil, apparently separated, as has been explained, by the space of about half an inch.



This experiment was repeated with palladium obtained from different sources, always with the same result. Experiments are in progress to determine the conditions under which this effect is produced, and to test some explanations which suggest themselves as to its nature.

On the determination of the rate of chemical change by measurement of the gases evolved. By F. E. Everard Lamplough, M.A., Trinity College.

[*Read* 18 May 1908.]

The evolution of a gas from a homogeneous liquid is a common phenomenon. In some cases the gas may have been stored in the liquid at a lower temperature or higher pressure, as in the evolution of carbon dioxide from ærated liquids, whilst in many other cases the gas is the result of a chemical action.

When a gas is given off as a product of a chemical action which occupies a measureable time, it might be supposed that when time has been allowed for the supersaturation of the liquid by the gas, the further rate of evolution of the gas would be a measure of the progress of the chemical change. This would be expected especially in those cases where very sparingly soluble gases result from the chemical action. Accordingly it is not surprising that when chemists began to investigate the dynamics of chemical actions, a measurement of the evolution of gas produced during a change was often used to determine the course of the reaction. Of the researches which have been prosecuted by this method, special reference will be made to the work of Veley, Hantzsch, and Cain and Nicoll.

By the introduction of solid substances into a liquid supersaturated with gas, the rate of the evolution of the gas is enormously increased; agitation of the liquid brings about the same result. This influence of solid particles on the rate of evolution of gases during chemical action has been especially studied by Veley, *Phil. Trans.* 1888, 257. It was found that the rate of evolution of gases during the progress of many chemical actions was greatly increased by the presence of inert substances such as silica, graphite, pumice and powdered glass.

On the other hand the comparative effect of agitation of the reacting liquids seems to have received little attention. It will however be shown that when a gas is formed during a reaction in homogeneous solution the liquid becomes highly supersaturated with the gas, and this storing up of the gas makes it impossible to investigate the rate of reaction by measurement of the rate of evolution of gas unless sufficient means are taken to prevent any supersaturation.

In the paper referred to, Veley came to the conclusion that the presence of silica, pumice and graphite increases the rate of evolution of gas because the velocity of reaction is increased by the

presence of these varied bodies, whereas the true explanation is that the gas stored up as a supersaturated solution is rapidly given off from the surface of the particles introduced. Veley also draws special attention to "periods of induction" in reactions

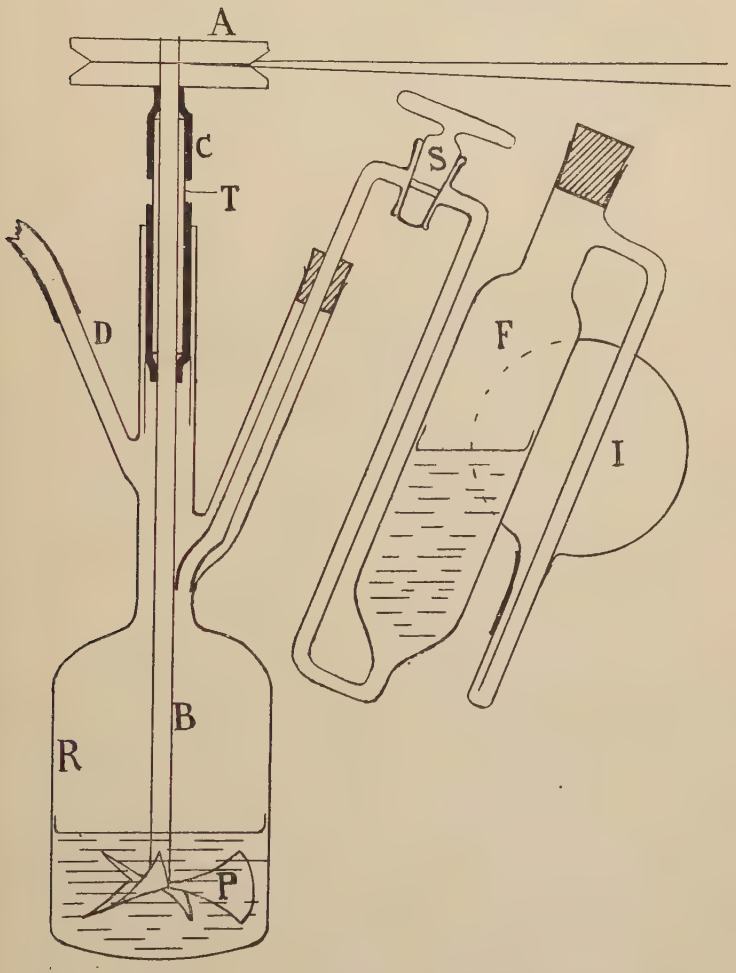


Fig. 1.

investigated by the rate of evolution of gases, and suggests that these may be explained by supposing that there are intermediate products in the reaction whose formation occupies time at the beginning of the reaction. But a more general cause is necessary to explain a general phenomenon. The explanation is however

very simple, for it will be shown later that no appreciable period of induction is observed if the liquid is vigorously agitated, whilst, if the liquid is not stirred, supersaturation of the gas takes place, in some cases to the extent of 100 times the normal saturation amount. The time taken to effect this supersaturation depends on the rate of the reaction and the nature of the gas. If however the solutions are vigorously stirred, supersaturation of the gas is avoided, and the rate of evolution of gas becomes a reliable method for the investigation of the course of the reaction.

The starting-point of this work was an attempt to elucidate the reaction between nickel carbonyl and iodine by measuring the rate of evolution of the carbon monoxide. During this investigation it was noticed that when the reacting liquid was allowed to remain at rest, a large amount of gas became stored up in the liquid in a state of supersaturation, a considerable volume of gas being expelled immediately the liquid was agitated. Hence the measurement of the rate of evolution of gas from the liquid at rest could by no means be taken as the measure of the velocity of the reaction. Experiments were therefore undertaken to determine whether the rate of evolution of gas from a solution thoroughly agitated by stirring was a true measure of the rate of reaction. For this purpose the decomposition of hydrogen peroxide in the presence of colloidal platinum was studied, because in this case the progress of the reaction could also be followed by means of titration.

Experimental method.

The apparatus used was the result of experience gained by many trials, and not a few failures. Fig. 1 represents the vessel in which the reaction was carried out. It consists essentially of a flask R, to contain the reacting liquid, fitted with a delivery tube D, connected with the burette in which the evolved gas was measured. Violent agitation of the liquid was produced by means of a platinum paddle P, rotated by the attached pulley A. (The bottom of the vessel was closed after the paddle had been inserted.) The paddle was generally rotated at 800 to 1200 revs. per min.; a higher velocity was used in the case of the decomposition of formic acid in sulphuric acid, the gas produced being held more tenaciously by this solvent. It was found that the temperature of 50 c.c. of alcohol was not raised as much as $\cdot 1^\circ$ by vigorous stirring for 5 minutes. The shaft B carrying the paddle rotated freely in a tube T; a rubber collar C was stretched over this tube, but was allowed to project a few millimetres so that the shaft B rotated stiffly in the collar. The rubber was lubricated with vaseline or glycerine and water, and formed an excellent airtight joint between

the rotating shaft and the guiding tube. It was found that the apparatus was airtight under a pressure of 30 cm. of water when the paddle was rotating at full speed.

In those cases where it was necessary to mix the solutions in an inert atmosphere, the apparatus *IFS* was employed. By pressing the rubber bulb *I*, the liquid in *F* was squirted through the stopcock *S*—which was then turned off—into the reaction vessel *R*, the time occupied being less than 2 seconds. To fill with the inert atmosphere, the whole apparatus was exhausted by an air-pump, and the gas in question was allowed to enter, the

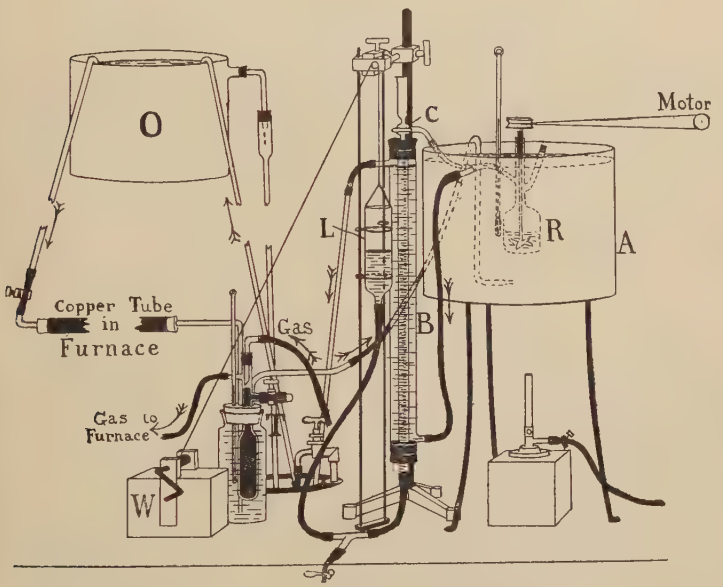


Fig. 2.

process being repeated three times. In all such cases the gas used was the same as that which was evolved in the course of the reaction.

Fig. 2 represents a general view of the apparatus. The part above described is immersed at *R* in the water bath *A*, the delivery tube being connected by means of a three-way cock *C* with the burette *B*. The liquid in the burette in most cases was the same as the solvent employed for the reaction, and in all cases was saturated with the gas evolved in the course of the reaction. The levelling tube *L* was arranged to slide on vertical guides and was raised, lowered or maintained at any point by means of the windlass *W*.

This arrangement was found to be of the greatest possible assistance in conducting the experiments, for the reactions were always allowed to take place at atmospheric pressure to avoid all possibility of leak or change in the solubility of the gas, and it was therefore necessary throughout the experiments gradually to lower the tube L so as to keep the liquid in the two arms at the same level.

In order to maintain the temperature of the gas in the burette the same as that in the reaction vessel, the former was provided with a water-jacket, and a current of water was passed first through the bath A, and then through the jacket of the burette. Some difficulty was experienced in maintaining this stream of water at a constant temperature, and it was found necessary to use a water cistern O provided with an overflow to keep the water at a constant level. Water was syphoned out from this cistern, passed through a copper tube, heated in a gas furnace, thence through a bottle containing the thermostat T, which regulated the supply of gas to the furnace, and then led into the water bath A. When working at a temperature of 60° to 70° it was found necessary to have further control over the temperature by means of a Bunsen burner, regulated by hand, under the water bath.

Decomposition of Hydrogen Peroxide.

For these experiments the stirrer and the inner surface of the vessel were completely covered with a coating of pure paraffin wax, so as to protect the solution from any effect which might be due to contact with the walls of the vessel, and all beakers, etc. in which titrations were performed were treated in the same way.

Two experiments were conducted as follows:—

Experiment I. A known volume of solution of hydrogen peroxide, whose strength had been determined by titration, was mixed with a known volume of a colloidal platinum solution at a given time. The mixture was at once poured into the reaction vessel and vigorously stirred for half a minute. After this short delay of known duration, measurement of the rate of evolution of oxygen was commenced. This measurement was continued until the rate was very slow, when the motor was stopped and the mixture poured into a large volume of dilute sulphuric acid and at once titrated. From this titration may be calculated the volume of oxygen which would have been evolved if the measurement could have been continued for an indefinite period. The total volume of oxygen which would be given off from the hydrogen peroxide solution can be calculated from the strength of the solution, and hence the gas lost before measurement may be determined.

This experiment therefore enables to find the volume of oxygen liberated from the solution, or the amount of decomposition, at any definite time after mixing.

Experiment II. This was performed in the same vessel, but without stirring, the quantities of the two solutions and the temperature remaining the same as before. After definite intervals of time 10 c.c. of the solution were withdrawn and titrated, and from these titrations the amounts of hydrogen peroxide decomposed were calculated.

In the following table is given the results of these experiments.

Time elapsed since mixing, minutes	Available Oxygen left in solution, calculated from titration, c.c. Experiment II.	Volume of gas evolved, calculated from titration, c.c. Experiment II.	Volume of gas evolved during experiment, c.c. Experiment I.
0	66·9	0·0	0·0
3	51·3	15·6	15·6
6	40·5	26·4	25·9
11	29·8	37·1	37·5
21	16·6	50·3	50·9
33	9·3	58·6	58·6

The agreement of the last two columns, which represent the result of investigation of the reaction by titration and by determination of the rate of evolution of gas from the agitated solution, is very close and furnishes a conclusive proof of the reliability of the latter method.

It should here be mentioned that at the time these experiments were being performed Prof. Bredig of Heidelberg was working at the same subject (*Zeits. für Electrochemie*, II. 525). He proved that, when means are adopted to keep the solution in agitation, the rate of evolution of oxygen from a solution of hydrogen peroxide with colloidal platinum is a true measure of the rate of decomposition of the hydrogen peroxide. Such agitation was produced by oscillating the reaction vessel which contained rods of glass. This method was found to answer well in this case, but I can scarcely think that it would be satisfactory in the case of more soluble gases such as carbon dioxide, or in the case of the evolution of carbon monoxide from sulphuric acid solution. In these cases my experiments have shown that very vigorous stirring is necessary to expel the whole of the supersaturated gas.

Decomposition of Diazobenzene Chloride.

This subject had previously been investigated by many workers, among whom may especially be mentioned Hantzsch (*Ber.* 1900, XXXIII. 2517), and Cain and Nicoll (*J. C. S.* 1902, 1412). In each case the rate of decomposition was measured by the rate of evolution of nitrogen from the solution, but the liquid was not stirred or agitated in any way. Hantzsch conducted the reaction in a flask which was filled to the neck with the solution, exposing only a small surface of liquid to the gas above the solution, and thus furthering supersaturation. From time to time the flask was tapped to release any bubbles which had been formed at the bottom of the flask. Cain and Nicoll used a similar method in their investigations.

Both workers found it was impossible to get results consistent with their theory of a unimolecular action throughout a greater range than about 30 to 80 per cent. of the total reaction.

The diazo salt was prepared according to the method given by Cain and Nicoll from an ice-cold solution of aniline hydrochloride, to which was added a solution of sodium nitrite. In some cases it was found convenient to use solutions which gave off a greater volume of gas than the capacity of the burette. In such cases when the greatest amount of gas that could be measured had collected in the burette, the three-way tap at the top was turned so as to cut off the reaction vessel; the levelling tube was then raised so as to bring the water again to the first division of the burette, the tap turned, and the measurement continued.

In conducting the experiments the requisite amount of diazobenzene chloride solution was taken and heated as rapidly as possible in a small flask over a Bunsen flame to a temperature one or two degrees higher than that of the water bath, so that after the slight cooling brought about by pouring through a funnel into the reaction vessel, the liquid should be as nearly as possible at the temperature of the bath. This occupied from ·6 to 1·6 min., and the liquid was then immediately poured into the reaction vessel and the motor started.

When the liquid had been violently churned for ·5 min. in order to get rid of the gas with which the solution had become supersaturated, and to bring the solution to the temperature of the water bath, the three-way tap at the top of the burette was turned and the measurement of the rate of evolution of gas was commenced. Measurement was continued until the evolution of gas had become extremely slow, in many cases only 1 or 2 per cent. of the diazobenzene chloride being undecomposed when the last observation was taken.

In the following tables are given observations taken during experiments performed at temperatures 36°·0, 44°·3, 51°·4, 60°·0, and 67°·0.

Temperature 36°.

Volume of gas evolved, c.c.	Time, minutes	Velocity constant
0	0·00	—
2	0·69	·0065
5	1·75	·0065
10	3·56	·0064
20	7·32	·0064
30	11·32	·0064
40	15·31	·0065
50	19·64	·0065
60	24·41	·0065
70	29·56	·0065
80	35·10	·0065
90	41·18	·0065
100	47·72	·0065
110	55·05	·0065
116	59·90	·0065
196	Calculated end point	— Mean ·0065

Temperature 44°·3.

Volume, c.c.	Time, minutes	Velocity constant
0	0·00	—
4	0·69	·0194
12	2·10	·0198
20	3·66	·0195
30	5·66	·0198
40	7·93	·0198
50	10·50	·0197
60	13·40	·0197
70	16·70	·0196
80	20·47	·0197
90	25·16	·0198
100	31·10	·0198
110	39·04	·0199
116	45·75	·0200
118	48·60	·0201
132	end-point, calculated	— Mean ·0198

Temperature 51°·4.

Volume, c.c.	Time, minutes	Velocity constant
0	0·00	—
2	0·17	·0509
8	0·72	·0501
16	1·47	·0514
26	2·49	·0524
34	3·47	·0519
42	4·57	·0516
50	5·87	·0511
58	7·37	·0523
66	9·22	·0506
74	11·47	·0508
86	16·87	·0503
94	24·00	·0503
98	32·90	·0504
99	37·70	·0510
100·2	end-point, observed	— Mean ·0511

In order to determine what law represents the relation between the rate of reaction and the amount of diazo salt left undecomposed,

Temperature 60°.			Temperature 67°.		
Volume, c.c.	Time, minutes	Velocity constant	Volume, c.c.	Time, minutes	Velocity constant
0	0·00	—	0	0·00	—
4	0·43	·147	10	0·41	·317
6	0·66	·149	14	0·59	·330
10	1·21	·148	18	0·80	·358
16	2·27	·149	22	1·09	·335
20	3·35	·146	28	1·59	·351
23	4·47	·146	32	2·19	·348
26	6·28	·146	36	3·35	·345
28	8·68	·151	38	4·93	·353
29	11·20	·146	38·7	end-point, observed	—
29·6	end-point, observed	—			Mean ·345
		Mean ·147			

the rate of evolution of gas was calculated from the differences between successive observations given in the second column in each of the preceding tables, and the values so obtained were plotted with the amount of gas already evolved.

The method of calculation adopted is most clearly described by an example. In the experiment performed at 44°·3 two successive observations were:

40 c.c.	7·93 min.
50 c.c.	10·50 „

Thus 10 c.c. of gas were given off in 2·57 min. and the rate of evolution of gas when 45 c.c. had been given off differed very little from 10/2·57, or 3·88 c.c. per min.

It was found that in these experiments the observations were so accurate as to give very smooth curves when the rates of reaction were plotted in terms of the amount of gas already given off.

As an example a table is given showing the results of calculations made from the observations taken in the experiment performed at 44°·3 as given above.

In Fig. 3 we have the result of plotting these calculated values with the amount of gas evolved. It will be seen that a straight line is obtained which cuts the line of zero rate of evolution of gas at 132 c.c. From this result it is obvious that the reaction is unimolecular throughout the range investigated, the rate of reaction being directly proportional to the amount of substance left undecomposed, if the end-point of the reaction is 132 c.c. When the value of the velocity constant K in the equation

$$K = \frac{1}{t} \log \frac{A}{(A - x)}$$

Rate of evolution of gas, c.c. per minute, when x c.c. have been evolved	x c.c.	Rate of evolution of gas, c.c. per minute, when x c.c. have been evolved	x c.c.
5·71	6	2·64	75
5·13	16	2·13	85
5·00	25	1·68	95
4·39	35	1·26	105
3·88	45	0·89	113
3·45	55	0·73	117
3·03	65		

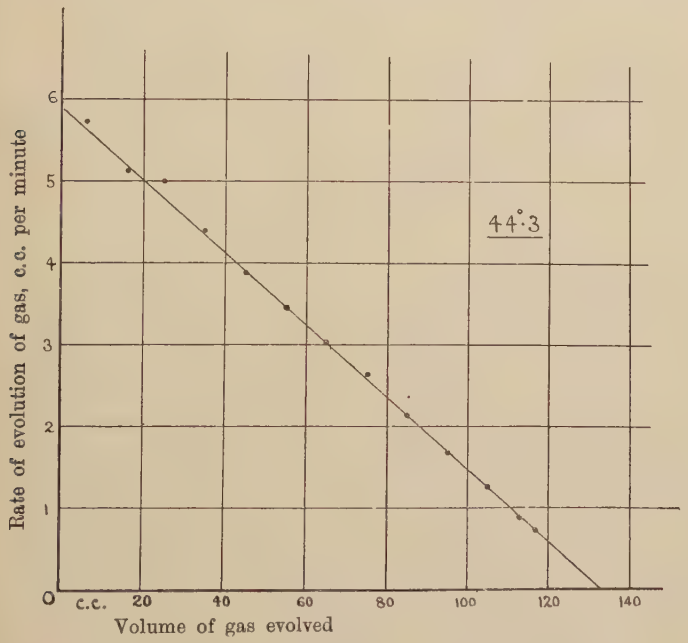


Fig. 3.

is calculated, using the value for A determined in this manner, the well agreeing numbers given in the earlier tables are obtained. In all the experiments at higher temperatures, the greater velocity of the reaction enabled readings to be taken very near the end of the reactions, the end-point being actually observed, and found to be in perfect agreement with the value calculated as above from the earlier observations, and the reactions were still unimolecular to the end. The range investigated however does not represent

the whole course of the reaction, because a delay occurs between the mixing of the solution and the first reading, this delay being 1·5 minutes at 51°·4 and lesser amounts in experiments at lower temperatures. Even assuming that there is no "induction period" of slow rate of reaction, and that the liquid throughout this delay is at the same temperature as that during the rest of the experiment, this time corresponds to a loss of 19·3 c.c. of gas unmeasured, and thus at 51°·4 the range investigated is from 16°/₀ to 99·0°/₀. In reality the range is greater than this, because the reacting liquid is at a lower temperature during part of the delay, and therefore decomposing less rapidly.

At 44°·3, with a loss of 1·3 minutes the range investigated is 5·8°/₀ to 90·4°/₀. At the lowest temperature, 36°, the loss in time was only 1·1 min. and the rate of reaction slow, causing a loss of not more than 3·2 c.c. of gas, so that the reaction was investigated from less than 1·6°/₀ up to 60°/₀. No departure from the law of a unimolecular action was observed throughout the above ranges, and therefore from the point at which the reaction has proceeded less than 1·6°/₀ the unimolecular equation accurately represents the course of the reaction, and there is no suspicion of any irregularity whatever at the beginning of the reaction.

Experiments were subsequently made at 40° and 55° to determine whether any thermal change due to the reaction caused the temperature of the reacting liquid to differ from that of the water bath. In these experiments a vessel of similar capacity to that described, and containing a thermometer, but not adapted for the measurement of evolution of gas, was used. At both temperatures it was found that during the time throughout which measurements had been recorded, the difference of temperature, if such existed, between the reacting liquid and water bath did not exceed ·1°.

The following table gives the values of the constant K and of the logarithms of the constant for the different temperatures at which the experiments were performed.

Temperature	K	Log K
36°	·0065	$\bar{3}$·8129
44°·3	·0198	$\bar{2}$·2967
[50°	·0424]	
51°·4	·0511	$\bar{2}$·7084
60°	·147	$\bar{1}$·1673
67°	·345	$\bar{1}$·5378

If these values for the logarithm of the constant K are plotted with the temperature, points lying very nearly on a straight line are obtained, and it may be calculated that the rate of reaction is increased 3·59 times by a rise in temperature of 10 degrees.

By interpolation the value for the constant at 50° is found to be ·0424, and this number is inserted in the above table.

The experiments of Cain and Nicoll, in which no attempt was made to remove the nitrogen with which the solution was supersaturated, led to values of K considerably lower than these, the constant at 50° being ·0298 and at 60° ·109. In many of the experiments there were greater variations in the values of the velocity constants than justify the conclusion that the action is unimolecular, even throughout the ranges from which observations were selected for calculation. This is only what might be expected in view of the fact that the rate of evolution of gas from the still solution depends only indirectly on the rate of its liberation from the decomposing diazo compound, being greatly influenced by the rate of evolution of the particular gas from its supersaturated solution.

The Decomposition of Formic Acid by Sulphuric Acid.

The reaction between formic acid and sulphuric acid was among those studied by Veley, *Phil. Trans.* 1888, p. 257.

He found that the action was bimolecular, and that when silica, pumice, etc. were added to the solution, the rate of evolution of gas was much increased, though the action remained bimolecular. In neither case was the solution agitated in any way.

To investigate this action the apparatus used was the same as that in the case of diazobenzene chloride, except that a stirrer, driven by a separate motor, was used to keep the water in the bath in constant motion.

The reaction-vessel was rinsed out several times with pure concentrated sulphuric acid. The air was then pumped out of the vessel, and pure carbon monoxide allowed to enter, and this process was repeated a second time. By this means air was removed from the vessel, and any possibility of action between formic acid and the oxygen of the air was avoided. The vessel was then placed in the water-bath, which was kept at a constant temperature of 72° C.

A reaction mixture was prepared by slowly adding 5 c.c. of an $N/2$ solution of sodium formate to 20 c.c. pure sulphuric acid, and cooling during the addition, so that the temperature of the solution just rose to that of the water-bath. Thus no time was lost in heating up the solution to the required temperature, and very little decomposition had taken place before the solution was introduced into the vessel.

The solution was then vigorously stirred whilst the reaction vessel was in contact with the air, and after about 15 seconds the three-way tap was turned so as to connect the vessel with the burette, and the evolution of gas was measured.

In the following table are given the readings and calculated values for the constant in the case of an experiment performed at 72° C., the law of a unimolecular reaction being assumed for the calculation of the constant.

Decomposition of Formic Acid by Sulphuric Acid.

Sodium formate $N/2$ solution 5 c.c. Temperature 72°.
Sulphuric acid, pure, $N/2$ solution 20 c.c.

Gas evolved, c.c.	Time, minutes	Constant K (calculated for unimolecular action)
0·3	0·00	—
8	0·83	·0635
12	1·28	·0647
20	2·28	·0659
28	3·85	·0649
36	5·07	·0650
45	7·38	·0642
53	10·36	·0640
59	13·99	·0639
65	22·09	·0640
66·8	29·79	·0646

End-point from curve 67·6 c.c.
Mean value of constant ·0645.

A second experiment, performed at 73°·8 C. with equally good results, gave a value of ·0770 for the constant; the composition of the reaction mixture remained unchanged.

The results of these experiments show that the decomposition of formic acid by sulphuric acid is a true unimolecular reaction.

Hence it follows that the action is simply the one represented by the equation:

$$HCOOH = H_2O + CO,$$

and not some such action as

$$HCOOH + HCOOH = (HCO)_2O + H_2O$$

followed by the rapid reaction:

$$(HCO)_2O = H_2O + 2CO,$$

a theory which was proposed by Veley to explain his conclusion that the action was bimolecular.

I wish here to acknowledge my indebtedness to Prof. Bredig, of Heidelberg, who, after this paper had been read before the Chemical Society, and an abstract published in *Proc. C. S.*, 1906, 280, was so good as to bring before my notice the fact that in an Inaugural Dissertation published in the University of Heidelberg in 1906, David M. Lichty had shown by a titration method that the decomposition of oxalic acid by sulphuric acid is a unimolecular reaction, and not bimolecular as found by Veley. In that paper also it is pointed out that Veley measured, not the velocity of reaction, but chiefly the velocity of evolution of a gas from its supersaturated solution.

Urea and Sodium Hypochlorite.

A few experiments were made to determine whether the action between urea and sodium hypochlorite was also one which could be described by a simple law. The solution of sodium hypochlorite was made by passing chlorine gas through a solution of soda. 40 c.c. of this solution were allowed to react with 10 c.c. of a solution of urea ·0169 gm. p. c.c., the hypochlorite being

Volume of gas evolved, c.c.	Time, minutes	Volume of gas evolved, c.c.	Time, minutes
0	0·00	40	9·00
0·6	0·55	50	14·00
1	0·77	55	18·33
2	1·00	60	25·16
4	1·43	61	27·28
10	2·50	62	29·75
15	3·28	63	32·78
20	4·08	67·6	2 hours
30	6·11		

present in considerable excess, the mixture being made strongly alkaline by the addition of a solution of soda. In one out of three well agreeing experiments the observations given in the above table were taken—intermediate readings being omitted for brevity.

It will be seen that the reaction takes some time to develop, but this induction period is much too great to be accounted for entirely by solution of the nitrogen first given off.

From Fig. 4, which gives the rates of evolution of gas plotted in terms of the amounts of gas evolved, it will be seen that no simple law expresses the connection between the rate of reaction

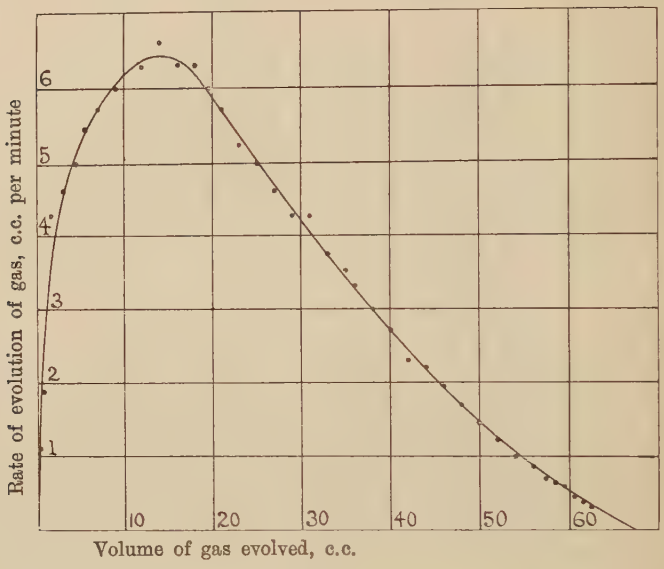


Fig. 4.

and the amount of urea left undecomposed. The rate of reaction reaches a maximum value and then gradually diminishes.

This result is in accordance with the fact that the change is complex, the number and nature of the products depending on the relative concentrations of the reacting substances.

The action of sodium hypochlorite on ammonium chloride, and on ammonium carbamate (in the latter only the nitrogen of the ammonium group being liberated—cp. Fenton, *J. C. S.* 1879, T. 12) was found to be so nearly instantaneous as to be incapable of measurement by this method. Urethane was not attacked by sodium hypochlorite, but on reaction with sodium hypobromite all the nitrogen was immediately given off.

Nickel Carbonyl and Iodine.

At the suggestion of Mr H. O. Jones, an attempt was made to investigate the mechanics of the reaction between nickel carbonyl and iodine. These substances react together according to the equation

$$Ni(CO)_4 + I_2 = NiI_2 + 4CO,$$

with the evolution of carbon monoxide (Dewar and Jones, *J. C. S.*, 1904, 207). Experiments were first performed with chloroform as the solvent, but later absolute alcohol was substituted because this solvent has the advantage of dissolving the nickel iodide formed during the reaction. Considerable difficulty was experienced in preventing the decomposition of the nickel carbonyl solution. The solution was eventually stored in a reservoir connected with a burette as illustrated in Fig. 5.

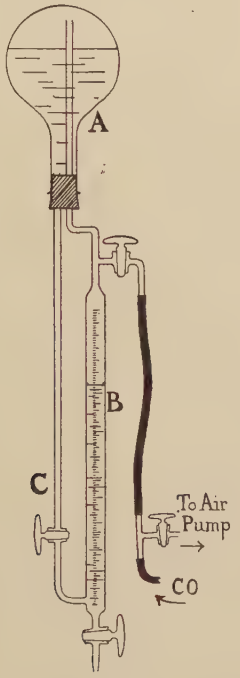


Fig. 5.

The inverted flask *A* which serves as the reservoir is connected by means of the tube containing the stop-cock *C* to the lower part of the burette, whilst the upper end of the burette is sealed to a tube which also passes through the rubber stopper of the flask *A* till it almost touches the end. To this tube is sealed a branch tube containing the stop-cock *B* which is connected to a reservoir of carbon monoxide, wash bottles containing sulphuric acid, potash and pyrogallol being interposed to purify and dry the gas. The solution of nickel carbonyl in the burette and in the flask

A was thus always in contact with pure carbon monoxide. By this method the solution nickel carbonyl could be kept for a month or more without decomposition. Two similar pieces of apparatus were used in which to store the solution of iodine and the pure solvent (alcohol) so that all the liquids used should be saturated with carbon monoxide, the gas given off through the reaction.

In order to compare accurately the strengths of the solutions of nickel carbonyl and iodine, the solutions were titrated together, the tint imparted to the solution by any free iodine present after long standing being used to indicate the presence of excess of that constituent.

In order to determine whether the products formed during the reaction in any way influenced the rate of the reaction, an experiment was performed in which solutions of nickel carbonyl and iodine of strengths in the ratio of 1 : 1·33 were used. 25 c.c. of the former, and 6 c.c. of the latter were made up to 110 c.c. and the rate of reaction measured. At the end of the reaction, 14 c.c. of liquid were abstracted, 8 c.c. of nickel carbonyl and 6 c.c. of iodine solution being added. The concentration of the reacting substances was therefore the same, but the solution contained in addition the products of the previous reaction. On measurement of the rate of reaction, however, it was found that there was no difference between the velocities of reaction in the two cases.

To determine the part which each constituent plays in the reaction, experiments were performed in which there was a large excess, either of one constituent or the other.

The rate of reaction was so great, especially when nickel carbonyl was present in excess, that it was found necessary to reduce the temperature to 0° before the velocity could be conveniently measured. To maintain this temperature without variation proved to be a difficult problem. After many attempts a fair measure of success was obtained. The bath containing a mixture of ice and water was well stirred, and by means of a spiral circulator revolving in a cylinder, the water was made to flow through the jacket of the burette and back again into the bath, so that both the reaction vessel and the burette were maintained at 0°.

The experimental results however did not appear to be capable of any simple interpretation. Straightforward results were not obtained when either constituent was in excess. The most remarkable observations were those made when the nickel carbonyl was in excess. As illustrated by the curves in Fig. 6 the action proceeded at a fairly uniform rate till a point was reached at which the reaction came to an almost abrupt stop, the colour of the solution

due to the iodine disappearing at the same instant. This result was repeated again and again. Sometimes readings taken only ·2 c.c. from the end-point showed no departure from the general course of the reaction; in fact, after the retardation was first detected in a particular experiment, there was never an evolution of more than ·2 c.c. of gas. It is not easy to speculate as to the cause of this strange phenomenon.

In the following tables are given the observations taken in two representative experiments in which nickel carbonyl was in large excess. The solutions of nickel carbonyl and iodine used in these experiments were of strengths in the ratio of 5 to 6·5, and it will therefore be seen that in experiments A and B the amount of nickel carbonyl present in the reaction mixture was equal to 6·5 and 12·5 times the equivalent amount of iodine respectively.

Experiment A.

Nickel Carbonyl solution	...	25 c.c.
Iodine „	...	3 c.c.
Alcohol	...	10 c.c.

Temperature 0°.

c.c.	minutes	c.c.	minutes
0	0·03	16	2·45
2	0·15	18	3·14
4	0·27	20	3·91
6	0·41	21	4·33
8	0·63	22	4·75
10	0·96	23	5·19
12	1·37	24	end-point
14	1·87		

Experiment B.

Nickel Carbonyl	...	26 c.c.
Iodine ...	...	1·6 c.c.
Alcohol	to make	38 c.c.

Temperature 0°.

c.c.	minutes	c.c.	minutes
0	0·03	7	2·17
1	0·31	8	2·58
2	0·54	9	2·98
3	0·81	10	3·41
4	1·09	11	3·82
5	1·45	12	4·24
6	1·82	12·25	end-point

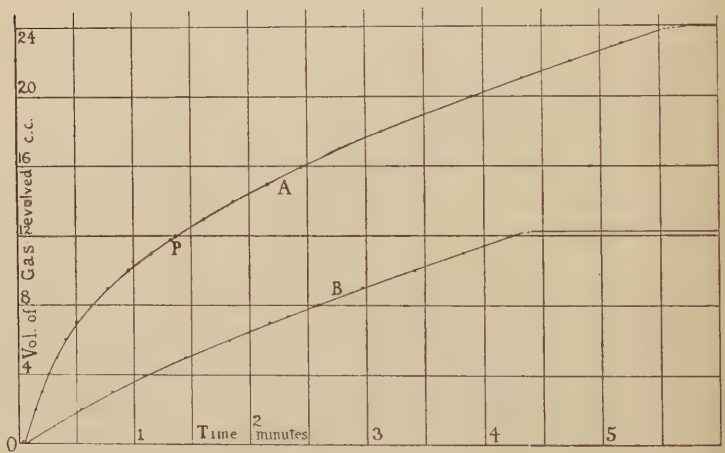


Fig. 6.

The curves in Fig. 6 represent the course of the evolution of gas in the above experiments. It will be observed that the rate with which the 12·25 c.c. of gas are given off in experiment B is the same as that with which the last 12·25 c.c. in experiment A are evolved. This fact is perhaps more clearly shown in Fig. 7, where the rates of evolution of gas in the two experiments are given in terms of the volume of gas which has been evolved, and it will be seen that the curve representing the rates of evolution in experiment B could be superposed on the latter part of the curve for experiment A so as to coincide almost exactly with it.

If on the curve *A* in Fig. 6 the point *P* represents the evolution of 11·75 c.c. of gas, then after the time represented by this point there was an evolution of 12·25 c.c. of gas, the amount given

off in experiment B. The point P in experiment A corresponds therefore to the commencement of measurement of evolution of gas in experiment B, and since from these two points the curve representing the evolution of gas in the two experiments is the same, there is good reason for thinking that (apart from the presence of the products of reaction in experiment A, which, as

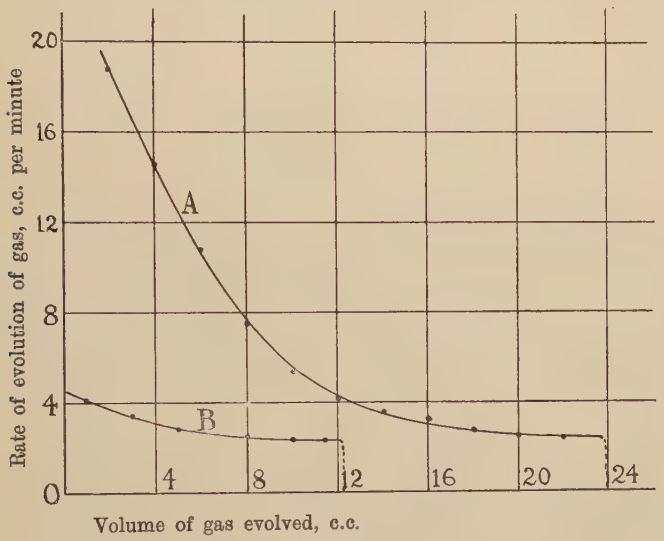


Fig. 7.

we have seen, do not influence the rate of reaction) the composition of the reaction mixtures at the time represented by the point P in experiment A is the same as that of the reaction mixture in experiment B at the commencement of measurement of evolution of gas. This would seem to indicate either that the reaction which results in the evolution of gas is not preceded by any change, or that such change is one which takes place very rapidly compared with the rate of the reaction which is measured by the evolution of gas.

The nature of the reaction which takes place between nickel carbonyl and iodine is not elucidated by experiments in which the iodine is present in large excess. Under these circumstances the action which takes place follows no simple law. A representative set of observations is given in the following table:

Nickel Carbonyl solution ...	5 c.c.
Iodine	20 c.c.

Temperature 0° C.

c.c.	minutes	c.c.	minutes
0	0·13	18	2·97
2	0·28	20	3·72
4	0·45	22	4·67
6	0·64	24	5·97
8	0·89	26	7·92
10	1·18	27	9·46
12	1·51	28	11·70
14	1·92	28·6	14·10
16	2·41		

When the rates of reaction are calculated from these observations, it is found that at first it is nearly bimolecular, but gradually changes so that towards the end of the reaction it is roughly unimolecular in character. This fact does not simplify the problem, nor does it in any way lead to an explanation of the remarkably abrupt termination of the reaction when nickel carbonyl is present in excess.

The rate of evolution of a gas from its supersaturated solution.

It has been shown that the rate of evolution of a gas from a solution which is not agitated cannot be taken as a measure of the progress of a chemical reaction, and in fact that the rate of evolution is only indirectly dependent on the velocity of the reaction.

By means of two experiments on the measurement of the gas evolved during a reaction, the manner in which the rate of evolution depends on the degree of supersaturation can be determined.

In Fig. 8 let OA and OB represent the progress of evolution of gas in the two experiments, OA being measured in the case where the solution was violently stirred, and OB without stirring. Then after the lapse of an interval of time OT, volumes of gas corresponding to aT and bT will be given off in the respective experiments. But the amount aT represents the total amount of gas which has been liberated during OT if the stirring is efficient, and therefore in the experiment without stirring, a volume of gas ab is stored up in the liquid.

Hence the rate of evolution of gas at the point b is that corresponding to supersaturation of the liquid with a volume of gas ab.

By this method it therefore becomes possible to investigate the relation between the rate of evolution of a gas and the degree of supersaturation.

It might be thought that a much simpler method of performing the work would be to supersaturate the solvent with the gas by means of pressure. The above method however gives at once a degree of supersaturation which otherwise could only be obtained by pressures up to 100 atmospheres and necessarily complicated apparatus.

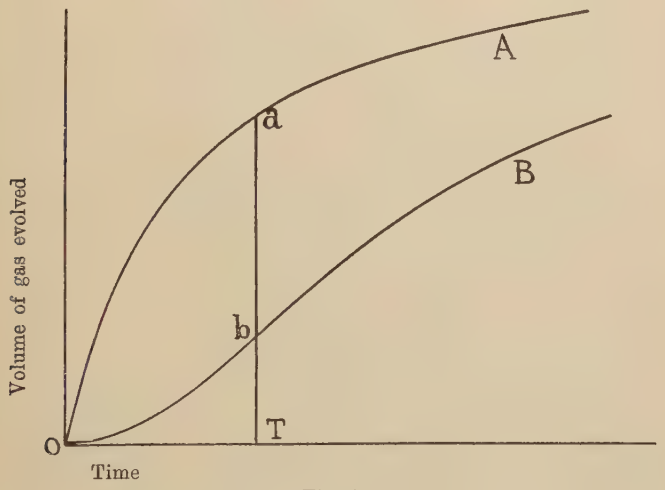


Fig. 8.

Experimental method.

The decomposition of diazobenzene chloride was investigated from this point of view.

The rate of evolution of gas when the solution was stirred was ascertained as before. In another experiment a reaction mixture of the same composition was introduced into the vessel, and the solution vigorously stirred, so that only the normal saturation amount could be retained by the liquid. In about 20 seconds the motor was stopped, the vessel being immediately connected to the burette in which the gas given off is measured. At the end of the experiment when the evolution of gas had become very slow, the motor was again started, and the remaining excess of gas driven off.

As the total amount of gas given off is thus known, the curve representing the evolution of gas can be plotted in conjunction with the curve obtained when the liquid was stirred.

For example, in one of the two experiments at 62°, an evolution of 65·1 c.c. of nitrogen was measured when the liquid was stirred. In the other experiment, without agitation of the solution, 56·2 c.c. were given off, and on completing the evolution of gas by the final stirring a further volume of 3·1 c.c. was obtained, making 59·3 c.c. in all. This amount is 5·8 c.c. less than that given off in the former experiment, and therefore in plotting the results of the second experiment the starting-point must be that point on the first curve which represents an evolution of 5·8 c.c. of gas, this volume being added to all the measurements of the amount of gas evolved; and since the 5·8 c.c. of gas were evolved in ·20 min. all the time measurements must likewise be increased by ·20 min.

In the following tables are given a few of the original readings taken in the two experiments.

Diazobenzene Chloride. 762 mm. 62° C.

The reaction mixture was kept in thorough agitation by stirring.

c.c.	minutes	c.c.	minutes
0	0·00	40	2·04
6	0·22	46	2·68
12	0·45	52	3·53
18	0·70	58	4·88
24	1·00	62	6·73
30	1·36	64	8·75
34	1·58	65	11·85

Diazobenzene Chloride. 762 mm. 62° C.

Volume of solution 37 c.c.

The reaction mixture was allowed to remain at rest.

c.c.	minutes	c.c.	minutes
0	0·00	26	3·17
1	0·55	34	4·33
2	0·75	40	5·60
3	0·92	46	7·70
4	1·03	51	11·60
8	1·45	54	16·80
14	1·97	56·2	25·50
20	2·53	59·3	after stirring

In Fig. 9 is given the result of plotting, according to the method explained above, all the observations in the two experiments from which the above sets of numbers were taken. The curve *OPA* represents the evolution of gas in the experiment in which the reaction mixture was agitated to remove the gas which is supersaturated in the solution; *PB* that in which the solution was at rest. It will be noticed that a point of inflexion occurs in the curve *PB* at about the point *B*, the rate of evolution of gas being greatest at this point. This corresponds to the maximum vertical distance *AB* between the two curves, this distance representing the amount of gas which remains supersaturated in the solution at rest. By drawing tangents to the curves the rates of evolution of gas at different points may be determined, and curves may be drawn in which the rates of evolution thus found are plotted in terms of the amount of gas which has been given off.

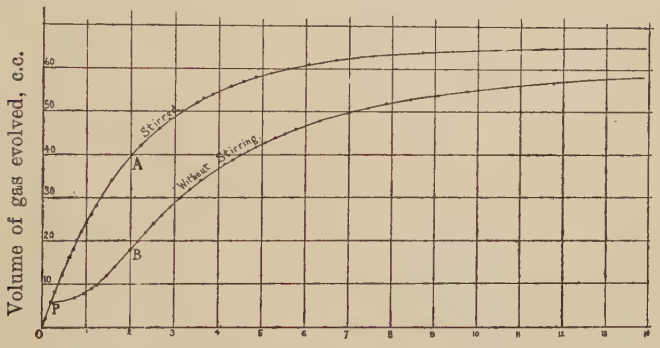


Fig. 9.

Fig. 10 gives the results obtained in this manner. It will be seen that the points which constitute the curve *CDE* lie very closely on a straight line, thus showing as before that the reaction as measured by the rate of evolution of gas from the agitated solution is unimolecular. On the other hand the curve *GHE* very clearly shows that the rate of evolution of gas from the unstirred solution rapidly increases from zero till the maximum value is reached at a point corresponding to an evolution of about 12 c.c. of gas. From this point the rate begins to diminish and continues to fall till all the gas is evolved.

It will be seen that between the points *H* and *F* the curve approximates to a straight line and for a short range the reaction appears to be nearly unimolecular. Near the end of the reaction however when a chemical change is complete, as shown by the rate of evolution of gas from the stirred solution, the gas given off from the unstirred solution is simply that which remains stored up

in a state of supersaturation and the law of a unimolecular reaction is no longer even approximately obeyed. The reaction therefore as measured by the rate of evolution of gas from the still solution resembles for a limited range a unimolecular action, and it is this resemblance which has been measured by Cain and Nicoll and other experimenters.

Experiments were also performed in which a solution of diazobenzene chloride was allowed to decompose, the rate of decomposition being measured by the evolution of gas from the

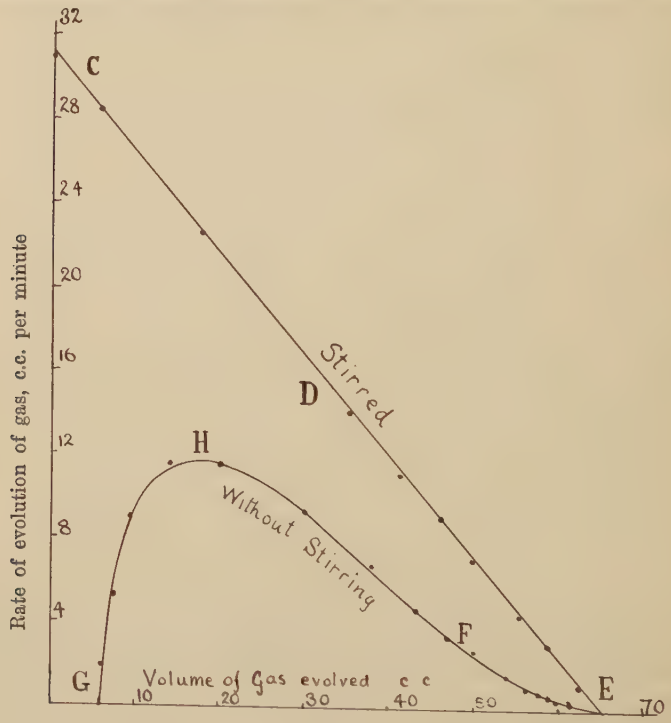


Fig. 10.

stirred solution. After a few observations had been taken, the stirring was arrested, and the rate of evolution of gas from the unstirred solution was measured. It was found in such experiments that the later observations show a break in the curve such as is represented by the line *PB* in Fig. 9, only a portion of the gas liberated by the decomposition being actually evolved, the remainder being stored up in the solution in a state of supersaturation. After an interval of time the solution was again agitated, and within a few seconds the whole of the gas thus

stored up in the solution was evolved, and the subsequent observations of the rate of evolution of gas from the stirred solution, and those taken in the earlier part of the experiment, were found to agree closely together with the theory of a unimolecular reaction.

This experiment furnishes the most conclusive evidence that the rate of evolution of gas from an unstirred solution is not a measure of the rate of reaction, and in conjunction with the comparison experiment on the decomposition of hydrogen peroxide described above, establishes the validity of the method of investigation put forward in the present paper.

From the above experiment the following results are obtained for the rates of evolution of nitrogen from its supersaturated solution and the corresponding amounts of gas stored in the solution, the volume of the solution being 37 c.c.

Rate of evolution of gas, c.c. per minute	Volume remaining supersaturated, c.c.	Rate of evolution of gas, c.c. per minute	Volume remaining supersaturated, c.c.
9	18·5	2·75	12·3
11·5	21·3	1·5	10·3
11·5	21·2	0·95	8·7
9·25	19·7	0·7	7·3
6·75	17·5	0·5	6·1
4·5	15·6	0·35	5·4
3·3	14·2	0·2	4·3

Fig. 11 gives the curve obtained by the graphical representation of these numbers. In the absence of very certain data as to the solubility of nitrogen at about 60° it is difficult to determine accurately the number of times by which the greatest amount of gas remaining supersaturated in the solution exceeds the volume normally dissolved by that volume of water at the same temperature. If the solubility of nitrogen is taken to be ·006 at 62°, a figure which does not seem too low, then the greatest degree of supersaturation obtained is nearly 100. This value has been exceeded in some experiments.

The largely increased rate of evolution of nitrogen for high degrees of supersaturation seems to be due to a great extent to effervescence of the solution.

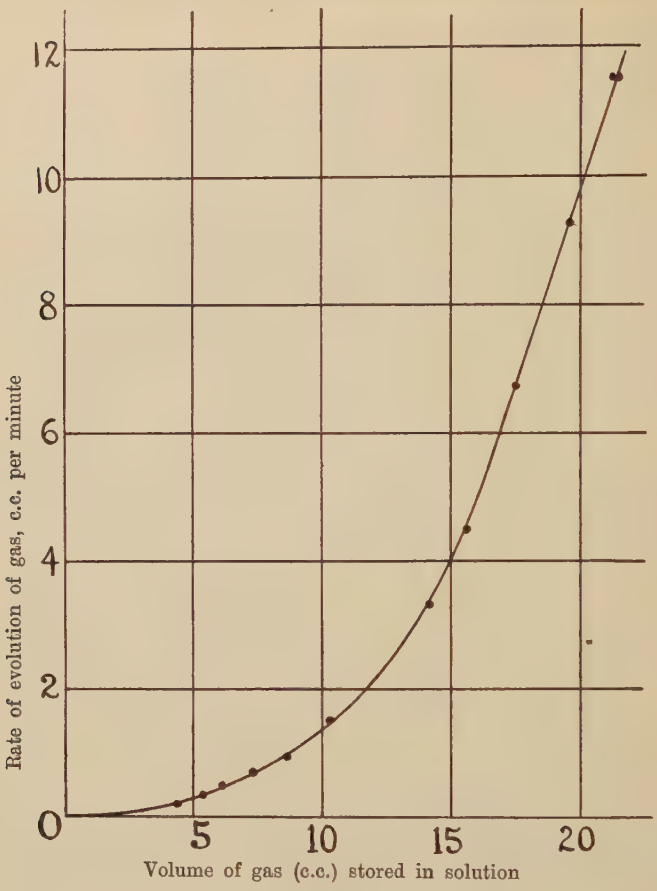

12
10
8
6
4
2
0
5
10
15
20
Rate of evolution of gas, c.c. per minute
Volume of gas (c.c.) stored in solution

Fig. 11.

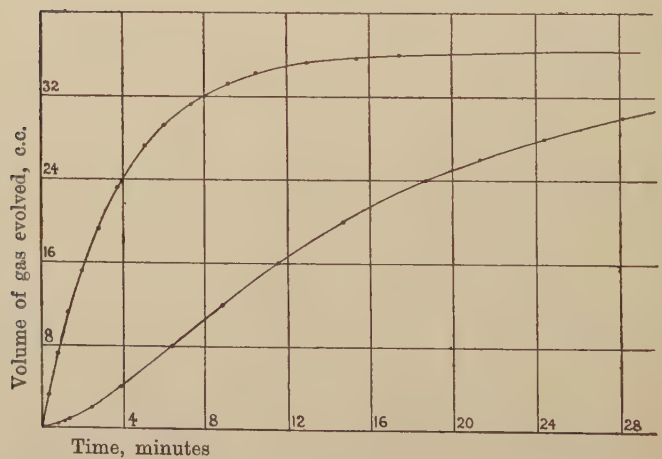

32
24
16
8
4
8
12
16
20
24
28
Volume of gas evolved, c.c.
Time, minutes

Fig. 12.

Hydrogen Peroxide.

A similar series of experiments were performed in the case of the decomposition of hydrogen peroxide in the presence of colloidal platinum. No change was made in the apparatus except that the stirrer and the interior of the reaction vessel were coated with a thin layer of paraffin wax as in the case of the earlier experiments with hydrogen peroxide. It was found that owing to the greater solubility of oxygen there was a correspondingly greater difference between the rates of evolution of the gas from the still and the agitated solution due to a larger volume of the gas remaining supersaturated in the solvent.

The observations taken during these experiments are represented graphically in Fig. 12. As before, the rate of evolution of gas from the supersaturated solution may be calculated in terms of the amount of gas stored up in the solution. The results obtained are given in the following table:

Rate of evolution of gas, c.c. per minute	Volume of gas stored in solution, c.c.	Rate of evolution of gas, c.c. per minute	Volume of gas stored in solution, c.c.
0·61	8·5	1·5	20·1
0·76	11·2	1·6	21·4
0·87	12·6	1·7	21·8
1·04	14·5	1·48	19·8
1·2	16·3	1·34	17·4
1·36	18·3	1·1	13·7

If we take the solubility of oxygen to be ·03 at 20°·4, then the greatest amount of gas supersaturated in the solution is 36 times the normal saturation volume of gas dissolved by the same volume of solution.

It will be noticed that for a degree of supersaturation of 30 times the normal amount dissolved by 20 c.c. of solution, the rate of evolution of oxygen gas is about 1·33 c.c. per minute. The rate of evolution of nitrogen at 62° from 20 c.c. of a solution whose degree of supersaturation is also 30 may be calculated to be about ·32 c.c. per min. from the experiment described above. To make this result comparable with the value for oxygen we must multiply by 5—the ratio of the solubility of oxygen at 20° to the assumed value ·006 for the solubility of nitrogen at 62°—so as to obtain the rate of evolution for the same degree of supersaturation and the same volume of gas supersaturated in the

solution. We thus obtain the value 1·62 c.c. per min. for nitrogen, which is rather near to the corresponding value 1·33 c.c. per min. for oxygen at 20°, in view of the doubtful accuracy of the number assumed for the solubility of nitrogen.

The most important results of this investigation may be summarised thus:

When a chemical reaction takes place in a solution resulting in the formation of a substance gaseous at ordinary temperatures, the solvent becomes supersaturated with the gas.

The degree of supersaturation may be so great that the solvent contains more than 100 times the normal amount of the gas, and from the solution the gas is gradually given off on standing. The excess of gas so dissolved may be almost entirely expelled in a few seconds by briskly agitating the liquid by rapid stirring.

Investigation of the rate of decomposition of hydrogen peroxide shows that under such conditions of efficient stirring the rate of evolution of a gas furnishes an accurate and reliable method of investigating reactions resulting in the formation of a gas. This has been proved also by Prof. Bredig.

The decomposition of diazobenzene chloride is a unimolecular reaction throughout, the velocity constant being much higher than the values previously assigned to it. The value of the velocity constant for the reaction is found to vary with change of temperature, increasing logarithmically with increase of temperature.

The reaction between nickel carbonyl and iodine (in alcoholic solution) is of a complicated nature, even in cases where either reagent is in considerable excess. When the nickel carbonyl is present in great excess a remarkable phenomenon is met with, the action proceeding in a steady manner until a point is reached at which it abruptly terminates almost without warning.

The decomposition of formic acid by sulphuric acid is a true unimolecular reaction, and not bimolecular, as it has been formerly considered.

The decomposition of urea in the presence of sodium hypochlorite does not follow a simple law. The rate of reaction increases to a maximum and then gradually diminishes.

The rate of evolution of a gas from its supersaturated solution may be determined from experiments performed with and without stirring. The rate of evolution does not depend in a simple manner on the degree of supersaturation, probably being greatly affected by the nature of the vessel, area of free surface, presence or absence of effervescence.

The author wishes to thank Mr H. O. Jones for his interest in the work and for many valuable suggestions throughout the course of the experiments.

Note on Russo's attempt to show differentiation of sex in the ovarian ova of the Rabbit. By Walter Heape, M.A., F.R.S., Trinity College.

[*Read* 26 October 1908.]

The question as to whether or not the conditions of environment exert influence on the proportion of the sexes produced by an animal is a matter of great interest. I am myself strongly of opinion such is the case and that physical conditions and food especially, that is to say the quality or quantity of food supplied to the mother and her individual capacity for assimilating food and transmitting nutriment to the ovary under varying conditions of metabolism, are factors of importance in determining the proportion of the sexes ultimately produced by all animals in which only a limited number of their ovarian ova come to maturity.

I have dealt with this matter somewhat fully in a forthcoming paper on "the proportion of the sexes amongst whites and coloured people in Cuba"; I would only here add that histological examination supports this view and that it would appear to have a very important bearing, not only on sex ratio but on many other problems concerned with the proportionate production of individuals carrying a variety of other characters.

On the assumption that the female germ cell is possessed of dominant sexuality, it would be of extreme value to discover means by which ovarian ova can be histologically recognised as M. or F. ova.

For this reason the publication of elaborate investigations on the subject by Russo[1] is calculated to excite considerable interest, for he thereby seeks to show: (1) that by means of the introduction of lecithin into the doe rabbit he can profoundly modify the proportion of the sexes produced by her; (2) that he can thereby also demonstrate histologically two kinds of ovarian ova, the one of which he declares to be M. the other F. ova.

So far as the former is concerned, an examination of the tables published by Russo has led my friend Professor Bateson to conclude they are not of statistical value, inasmuch as it would appear the cases recorded are selected cases and do not include all births[2].

[1] Russo, "Modificazioni sperimentali dell' elemento epitheliale dell' ovaia dei mammiferi," *Atti R. accad. Lincei, Roma*, vol. xvi. 1907; "Metodi adoperati per aumentare artificialmente la produzione del sesso femminile nei conigli," etc. *Rend. d. R. accad. Lincei, Roma*, vol. xvi. 1907; "Sulla origine e sulla funzione dell' apparato mitocondriale nelle cellule sessuali dei mammiferi," *Proc. acad. Gioenia, Sci. Nat. Catania*, 1908.

[2] Bateson, "Heredity of sex," *Science*, No. 698, vol. xxvii. 1908.

At Prof. Bateson's suggestion I have examined Russo's histological evidence and compared his figures with my own preparations of rabbits' ovaries, with the following result:

Russo's histological methods are, so far as I understand them, specially adopted to enable him to demonstrate the existence of fatty matter in the ovum and surrounding tissue. He describes and figures two kinds of ova; the one in which fat is more or less abundantly evidenced both in the ovum, in the zona radiata and, in some cases, in the surrounding follicular tissue; the other in which no such deposit of fat is seen; and he maintains, as I understand him, that while the former are F. ova, those in which no fatty matter is present are M. ova.

In view of the belief which is very generally held and which I admit I am myself strongly disposed to credit, that females require more nutriment than males for their successful development, this demonstration by Russo deserves special attention.

He figures many ova of different ages, from very young to fully mature ova, in which fatty material is present in varying degree, and it may be that the lecithin he supplied is responsible for some of that fat. But it is I believe known that lecithin is normally present in the yolk of eggs, and we are at once arrested by the query why, if that be so, do certain ova figured by him show no sign of its presence.

He figures two such ova and especially refers to them as M. ova.

The first of these is an ovum lying in the centre of a large follicle surrounded by its discus proligerus. It is drawn on too small a scale to admit of detailed criticism, but there are indications that foreign elements are present among the cells of the discus. I find examples among my own preparations of a similar appearance, and when examined under a higher power it is seen to be due to the presence of leucocytes. I have no doubt whatever that the presence of leucocytes in a follicle is a sure sign of degenerative change, and though I cannot assert Russo's figure is that of a degenerating follicle, it is not free from the suspicion that such is the case, and it is to be regretted he did not give a more detailed drawing of it.

Of the second "male" ovum figured by Russo there can be no such doubt. He calls it a ripe ovum ready to be discharged from the ovary, and it is represented possessed of a nuclear spindle, lying free in a sharply-bounded cavity the cells surrounding which are more or less cubical or flattened. The cavity is either a hole in the discus or the follicular cavity itself, probably the former. The specimen is highly magnified and only a few of these surrounding discus (follicular?) cells are included in the drawing.

Now no such condition is ever seen in the healthy, ripe follicle

of a rabbit's ovary. The discus proligerus cells are always attached to the zona during the growth of the ovum, it is in fact through them that nutriment is conveyed to the ovum. They are at first columnar, becoming more fusiform with the growth of the ovum; as the latter attains maturity they are still further withdrawn until eventually, when maturation takes place, they are exceedingly attenuated, remaining attached to the zona only by fine processes which readily break away when the follicle ruptures, thus permitting the ovum to escape free from them. But in the healthy follicle these cells are always present either as columnar or fusiform cells, never as flattened cells.

The so-called ripe "male" ovum figured by Russo has nothing in common with this condition; it is, in fact, not a ripe ovum, it is an immature ovum lying in a cavity (in the discus) in a degenerate follicle, and I can only suppose he has jumped to the conclusion it is ripe because it possesses a nuclear spindle. But here again he is wholly mistaken; a nuclear spindle, and polar bodies also, are commonly to be found in ovarian ova which, in consequence of degenerative changes, have lost connection with their discus cells; such ova may even exhibit partial segmentation. Unless I am entirely mistaken such premature maturation phenomenon is associated with cessation in the supply of nutriment to the ovum, precisely as in the case of the healthy maturated ovum, with its polar bodies, where discus cells have been withdrawn by normal causes and the supply of nutriment thus curtailed or stopped entirely.

It is astonishing that recognition of these facts should have escaped Russo, but it does not seem that he is familiar with various forms and degrees of degeneration commonly met with in the rabbit's ovary. Certain of his figures of female ova are not free from suspicion of degenerate change though it is much less marked in them and is chiefly suggested by the condition of the zona.

I find in my preparations that not infrequently the zona is absorbed, and when that is so the ovum loses connection with the discus cells and degenerates. In some of Russo's figures I judge there is indication of the absorption of the zona, but it is important to note that unless the draughtsman was on the look out for this he might give the impression of degeneracy when perhaps it was not there; the fact that these ova are still amply supplied with fat is evidence that degeneration, if it is in progress, has not gone far.

It is impossible to avoid remarking that of all the ova which must have passed under his observation Russo figures only two which, so far as I can find, he directly refers to as "male" ova; and it is significant that of these two, one is undoubtedly de-

generate and the other suspiciously similar to examples in my possession of an early stage of that condition.

Thus it is with great regret I am obliged to conclude he has not proved what, at first sight, seemed to be such a clear exposition of the correctness of my own belief.

At the same time it is to be noted that the ova he figures which have absorbed lecithin, are represented as having done so in very various degrees. If this be so it is of interest inasmuch as it bears upon the constitutional variability of ova and of the power to affect them, to stimulate or to retard the growth and maturation of certain of them, by means of different foods supplied to the mother. I have elsewhere shown there is an overwhelming mass of evidence in favour of the view that F. larvae require more nourishment than do M. larvae for their successful development, and that the same relative requirements are probably evinced by ovarian ova of different sexes; it is not impossible then that the variable amount of lecithin in different healthy ova, shown by Russo, may have important bearing on this point.

A further note on the eggs of the hermaphrodite Angiostomum nigrovenosum. By S. A. McDowall, M.A., Trinity College.

[*Read* 26 October 1908.]

A re-examination of the material has rendered necessary one or two corrections in my preliminary note on the nuclear phenomena in these eggs. (*Camb. Phil. Soc. Proceedings*, Vol. XIII, Pt. V, pp. 309—312.)

A ring formation does take place after the contraction-phase, but the rings appear not to be completed, for the ends of the chromosomes do not fuse.

The rings open out, often forming ω-shaped chromosomes which may or may not become V-shaped before they finally flatten into the pseudo-spireme. As a rule the ω simply becomes more and more flattened until a straight strap is formed.

In the next stage two nodal bodies seem to appear earlier than the rest, and they are, for a time at least, decidedly larger. Probably these are the forerunners of the large double-chromosome mentioned in my previous note.

Sometimes there are only five double chromosomes; whether this is due to the section or no, I am still uncertain.

It is just possible that the nucleolus has some important function: in the secondary-reticulum stage it seems occasionally to suffer unequal division, the larger part disintegrating immediately, the smaller persisting for a time; but this is uncertain.

PROCEEDINGS AT THE MEETINGS HELD DURING THE SESSION 1907—1908.

ANNUAL GENERAL MEETING.

October 28th, 1907.

In the Optical Lecture Room.

Dr Hobson, President, in the Chair.

The following were elected officers for the ensuing year:

President:

Dr Hobson.

Vice-Presidents:

Mr D. Sharp.
Mr S. Ruhemann.
Prof. Thomson.

Treasurer:

Mr H. F. Newall.

Secretaries:

Mr A. E. Shipley.
Dr Barnes.
Mr P. V. Bevan.

Other Members of the Council:

Mr A. Hutchinson.
Mr F. F. Blackman.
Mr H. W. Richmond.
Mr F. G. Hopkins.
Mr A. Harker.
Prof. Larmor.
Dr Duckworth.
Mr W. G. Fearnsides.
Dr Sell.
Mr W. E. Dixon.
Prof. Wood.
Prof. Hopkinson.

The following Communications were made:

1. On the Longitudinal Impact of Metal Rods with rounded ends. (Second Paper.) By J. E. Sears, B.A., St John's College. (Communicated by Professor Hopkinson.)

2. On the Fatigue of Secondary Radiation due to Radium Rays. By J. A. Crowther, B.A., St John's College. (Communicated by Professor Thomson.)

3. Laws of Motion. By P. V. Bevan, M.A., Trinity College.

4. On the asymptotic approximation to functions defined by highly convergent product-forms. By J. E. Littlewood, B.A., Trinity College. (Communicated by Dr Barnes.)

5. Ionisation by Ultra-Violet Light. By Professor Thomson.

November 11*th*, 1907.

In the Optical Lecture Room.

Dr Hobson, President, in the Chair.

The following was elected a Fellow of the Society:

C. C. Dobell, B.A., Trinity College.

The following Communications were made:

1. A critical description of three cases of single hypogastric artery in the human foetus. By W. L. H. Duckworth, M.D., Sc.D., Jesus College.

2. On the Inheritance of White in Poultry. By R. C. Punnett, M.A., Gonville and Caius College.

3. Sexual Phenomena in the Free-living Nematodes. (Preliminary note.) By F. A. Potts, M.A., Trinity Hall.

November 25*th*, 1907.

In the Chemical Laboratory.

Dr Hobson, President, in the Chair.

The following were elected Fellows of the Society:

C. L. Boulenger, B.A., King's College.
A. S. Eddington, B.A., Trinity College.
E. Gold, M.A., St John's College.
T. H. Laby, B.A., Emmanuel College.
W. Malden, M.D., Trinity College.
J. Mercer, B.A., Trinity College.
R. N. Salaman, M.D., Trinity Hall.

The following Communications were made:

1. The orientation of 3 : 5-dichloropyridine. By W. J. Sell, Sc.D., Christ's College.

2. The action of Metallic Magnesium on certain aliphatic acids, and the detection of formic acid. By H. J. H. Fenton, Sc.D., Christ's College, and H. A. Sisson, B.A., Clare College.

3. Some Colour-reactions of organic acids with phenols. By H. J. H. Fenton, Sc.D., Christ's College, and G. Barr, B.A., Christ's College.

4. Contributions to the knowledge of the Oxaloimidochlorides. By S. Ruhemann, M.A., Gonville and Caius College.

5. The absorption spectra of collidine and 9-chlor-collidine. By J. E. Purvis, M.A., St John's College, and W. H. Foster, M.A., St John's College.

6. The decomposition and nitrification of sewage (1) in alkaline solutions, (2) in distilled water. By J. E. Purvis, M.A., St John's College, and R. M. Courtauld, M.A., Pembroke College.

7. The influence of light and of copper on fermentation. By J. E. Purvis, M.A., St John's College, and W. A. R. Wilks, B.A., Gonville and Caius College.

8. Resolution of optically active ammonium salts by means of tartaric acid. By H. O. Jones, M.A., Clare College.

9. Studies on Platinocyanides. By L. A. Levy, B.A., Clare College. (Communicated by Dr Fenton.)

10. Orientation of substituted brom-anilines. By J. R. Hill, B.A., St John's College. (Communicated by Mr H. O. Jones.)

11. On the Solutions of Ordinary Linear Differential Equations having Doubly Periodic Coefficients. By J. Mercer, B.A., Trinity College. (Communicated by Dr Barnes.)

January 27th, 1908.

In the Anatomy and Physiology Lecture Room.

Dr Hobson, President, in the Chair.

The following was elected a Fellow of the Society:

Hugh Scott, B.A., Trinity College.

The following was elected an Associate:

E. P. Metcalfe, Emmanuel College.

The following Communications were made:

1. (1) Exhibition and description of a portion of a fossil jaw of one of the *Equidae* (British East Africa). (2) Exhibition of Zebra skins (13) and skulls (4) from British East Africa, with special reference to the problem of the centre of distribution of the three species of Zebras. By Professor Ridgeway, Gonville and Caius College.

2. On a new genus of *Ixodoidea*, together with a description of eleven new species of Ticks. By Professor Nuttall, Christ's College, and C. Warburton, M.A., Christ's College.

3. (1) Description of a microcephalous new-born Pig. (2) Report on the brain of a microcephalous idiot. By W. L. H. Duckworth, M.D., Sc.D., Jesus College.

February 10*th*, 1908.

In the Cavendish Laboratory.

Mr S. Ruhemann, Vice-President, in the Chair.

The following was elected a Fellow of the Society:

C. Shearer, B.A., Trinity College.

The following Communications were made:

1. (1) On the nature of the γ rays. (2) On the velocity of cathodic secondary radiation. By Professor Thomson.

2. On the spectrum of the discharge from a glowing lime cathode in Mercury Vapour. By F. Horton, B.A., St John's College.

3. An example of complex double integration. By Dr A. C. Dixon.

February 24*th*, 1908.

In the Botany School.

Mr D. Sharp, Vice-President, in the Chair.

The following Communications were made:

1. (1) Relation between the Geographical distribution and the classification of the Onychophora. (2) On the method of impregnation in *Peripatus*. By Professor Sedgwick.

2. Exhibition and description of Welwitschia collected by Professor Pearson. By Professor Seward.

3. Note on a method of demonstrating the syncytial appendages of the placental villi. By W. L. H. Duckworth, M.D., Sc.D., Jesus College.

4. On six new species of the *Ixodoidea*. By W. F. Cooper, B.A., and L. E. Robinson.

5. Note on the protozoal, intestinal parasites in Frogs and Toads. By C. C. Dobell, B.A., Trinity College.

6. On Integral Equations. By H. Bateman, M.A., Trinity College.

March 9th, 1908.

In the Chemical Laboratory.

Dr Hobson, President, in the Chair.

The following was elected a Fellow of the Society:

T. H. Riches, M.A., Gonville and Caius College.

The following Communications were made:

1. (1) On the formation of carbonic acid and lactic acid during muscular contraction and rigor mortis. (2) On the complete hydrolytic decomposition of egg-albumin at 180° C. By P. W. Latham, M.D., Gonville and Caius College.

2. (1) Synthesis of Pyrone compounds from acetylene acids. (2) The action of mustard oils on ethyl carbonate and ethyl cyano-acetate. By S. Ruhemann, M.A., Gonville and Caius College.

3. The absorption spectra of some compounds derived from pyridine and collidine. By J. E. Purvis, M.A., St John's College.

4. The limitations of the copper-zinc couple method in estimating nitrates. By J. E. Purvis, M.A., St John's College, and R. M. Courtauld, M.A., Pembroke College.

5. A double sulphate of Guanidine and aluminium. By F. Ferraboschi, B.A., Clare College. (Communicated by Dr Fenton.)

6. On the property of a double-six of lines, and its meaning in hypergeometry. By H. W. Richmond, M.A., King's College.

7. On energy Accelerations and Partition of Energy. By C. W. Follett, B.A., Trinity Hall.

May 4th, 1908.

In the Optical Lecture Room.

Dr Hobson, President, in the Chair.

The following were elected Fellows of the Society:

W. J. Harrison, B.A., Clare College.
J. B. Hubrecht, B.A., Christ's College.
A. M. Smith, B.A., Emmanuel College.

The following Communications were made:

1. (1) The Geographical Distribution of the Acarine family Oribatidae. (2) On some new and obscure species of the genus *Haemaphysalis* of the Ixodidae. By C. Warburton, M.A., Christ's College.

2. On the Fauna of the Bradford Coke Bed Effluent. By Dr A. Meixner. (Communicated by Mr A. E. Shipley.)

May 18th, 1908.

In the Optical Lecture Room.

Mr S. Ruhemann, Vice-President, in the Chair.

The following Communications were made:

1. Radioactivity of solutions of Potassium salts. By N. R. Campbell, M.A., Trinity College.

2. The absorption spectra of some compounds of pyridine. (Second paper.) By J. E. Purvis, M.A., St John's College.

3. Further researches in the theory of Divergent Series and Integrals. By G. H. Hardy, M.A., Trinity College.

4. Some reactions of Phenyliodide chloride and iodosobenzene acetate. By H. H. Hodgson, M.A., Trinity College. (Communicated by Mr H. O. Jones.)

5. On Integral Forms and their connexion with Physical Equations. By R. Hargreaves, M.A., St John's College.

6. The Determination of the rate of chemical change by measurement of the gases evolved. By F. E. E. Lamplough, M.A., Trinity College.

7. A preliminary note on an effect observed when Palladium foil is heated in air at a low pressure. By H. V. Gill, Downing College. (Communicated by Professor Thomson.)

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